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WIMSHURST'S INFLUENCE MACHINE.

THE Wimshurst influence machine is now extensively known, and is fast replacing other electrostatic generators in use in physical laboratories. Its rapid introduction is due mainly to three characteristic features, viz.: (1) Its remarkable independence of atmospheric conditions; (2) its power of self-excitement; and (3) its constancy of polarity.

It has given every satisfaction without any preliminary treatment in crowded lecture theaters in which other influence machines behaved most disappointingly. It has also been frequently placed in trying and even in extreme hygrometric conditions, and found to work admirably. As to initial electrification, it never wants any. As soon as the varnished plates with their metallic sectors are fitted with their brushes and spun round in proximity to each other, a charge is invariably and rapidly built up. One side of the machine becomes positive with respect to the other, and this electrical state is maintained as long as the machine is kept working.

The machine, which is represented in the illustration, which we take from *Engineering*, is the latest one constructed by Mr. Wimshurst in his amateur workshop at Clapham. It consists of eight of the well-known plates—which may henceforth be aptly called by the distinctive appellation of Wimshurst plates—each being 2½ feet in diameter and carrying sixteen sectors. When the plates are rapidly rotated in opposite directions, a high degree of electrification is produced. In order to diminish as much as possible the loss of charge arising from the usual causes, all the conductors, and even the rods carrying the metallic brushes, are covered with a thick coating of gutta-percha, and the whole apparatus is inclosed within a tightly fitting and dust-excluding glass case. In like manner, the brass rods which lead from the prime conductors to the outside terminals are carried up through glass tubes. By these means, the losses due to leakage and discharge to neighboring bodies are greatly reduced, and the efficiency of the machine correspondingly increased.

Some idea of the electrical power developed by this machine may be formed from the easily reproducible fact that every turn of the handle gives six sparks each of 8 inches in length. One complete revolution, therefore, generates a quantity of electricity corresponding to a disruptive discharge of 4 feet length. Sparks of 10 in. and 12 in. are readily obtained. Some of the former have been photographed, and are remarkably beautiful, showing in a marked manner the multiple and branching character as well as the zigzag path of the discharge between terminal and terminal.

The condensers used were made of ordinary hock bottles, and the discharge was accompanied by an almost unbearable snapping noise, comparable in loudness to a pistol shot.

This machine was specially constructed for the course of afternoon lectures now being given by Professor George Forbes at the Society of Arts. In one of these, in order to show the strain produced in a dielectric medium when acted upon by an electromotive force, the Professor endeavored to repeat a famous experiment of Dr. Kerr's. Two wires leading from the terminals of the machine dipped into mercury contained in two small glass bulbs. These were immersed at a little distance from each other in a cell containing carbon disulphide. A beam of polarized light was then passed through the liquid, and the analyzer turned until the light was cut off. It was duly explained that the stress to which the liquid dielectric (CS_2) would be subjected on turning the machine would be made manifest by the reappearance of the light on the screen. The stress, however, proved to be so great as to noisily shatter the glass bulbs before any optical effect could be perceived. The point was thus demonstrated in an unmistakable and probably unwished-for manner. The same principle of strain was again illustrated in the care of Leyden jars by separating the terminals of the machine as far as possible and rapidly rotating the plates. Though the walls of the jars were unusually thick, they were unable to resist the intense electrostatic strain produced by the high electromotive force of the machine. This electromotive force has been measured in terms of that of a Daniell's cell, and found to be 50,000 volts, while the current has been estimated at the $\frac{1}{5000}$ of an ampere.

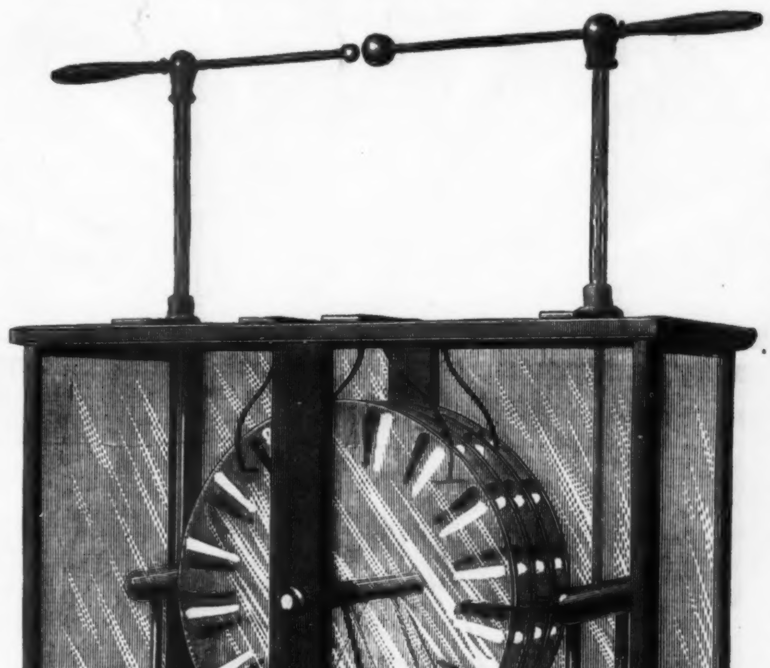
In an elementary class-book* on electricity just published, we notice that one of the sections is headed, "The Voss or Wimshurst Machine." This evidently implies the identity of the two electrostatic generators, which is an error. Moreover, when the author, proceeding with his description of the Voss, says that "one plate is fixed," he has said quite enough to convince any one who has ever seen a Wimshurst that the two machines are essentially different. As to the principle involved, they, as well as all other influence machines, are based upon Nicholson's "doubler."

In this connection it may be interesting to state that a series of measurements has been made for the purpose of comparing the quantity of electricity developed respectively by a Voss and a Wimshurst machine provided with plates of equal diameter, the result showing that the latter yields three and a half times as much as the former.

The machine which is pictured here was exhibited at the recent Royal Society conversazione. It attracted considerable attention, as did also the photographs of the spark discharge.

We give in another article in this number particulars for the construction of a two plate machine.

* "Electricity Treated Experimentally," by L. Cumming, M.A.



THE WIMSHURST ELECTRICAL MACHINE.

THE WIMSHURST INDUCTION MACHINE.

THE Wimshurst is essentially an induction machine, as the electricity is not the result of friction, as in those of the cylinder form, but "induced" on the principle of the electrophorus. All those who have gone very far in the study of electricity know that there is, for example, a great difference in the *conditions* of the primary and secondary current in a Ruhmkorf coil. Owing to chemical action in the cell, a current is set up in the primary coil; but when this is surrounded by another coil under given conditions, a secondary current is set up, which in its character is very different to the primary.

The first, for example, might not be able to leap across a hundredth part of an inch, but might at the same time produce great chemical or mechanical change, while the induced current will produce little if any chemical change, but will give the most violent physical shock, and has such intensity that it can leap over a space in air perhaps a hundred times greater than the primary.

My purpose will be simply to give such instruction as shall enable the intelligent worker to produce for himself the machine, but not to give any theory as to the mode of induction. Indeed, it is a subject so far hid in great mystery. The inventor himself, I think, is hardly sure, and by the various theories given, one is led to the conclusion that the problem is unsolved. But one may naturally ask, seeing there are already the Ruhmkorf coil and the Winter frictional machine, both of which are capable of producing electricity of high tension, What is the advantage of the Wimshurst over these?

In the first place, although we cannot conceive of anything more compact and beautiful than the coil, unique in some sense, yet all who have worked on one know how great is the difficulty in making a large one. There are but very few, comparatively, who have succeeded in making one to give a spark more than 1 or 2 inches in length, and the difficulty increases at a rapid ratio with every additional length of spark; and then as to cost, as no one can expect to get more than an inch from a mile of wire, it will be seen that the cost is considerable.

In reference to the plate or cylinder machine, the great drawback is that the state of the atmosphere affects it so readily. If the least moisture in a warm room condenses on the plate, it is fatal to all success.

The advantage of the Wimshurst machine is that, in contrast to the Ruhmkorf, both in money and labor, it costs only a fraction; and in reference to the ordinary plate machine, it gives with the same size plate a much longer and more rapid discharge, and practically is indifferent to climatic conditions. Now having said so much to inspire the learner with the requisite enthusiasm, we will proceed to our work.

The essential parts of the machine are as follows: 1. A bed or stand. 2. Two glass disks. 3. Driving wheels for rotating disks. 4. Condensers, with combs and dischargers. 5. Neutralizing brushes and rods. I have given three views of the machine, viz., side elevation, end elevation, and plan as seen from the top. The letters refer to the same parts in each figure. The bed may be made of good pine, but will be far more satisfactory if made of mahogany. For the ends take two pieces, 12 by 4 by 1 inch; sides two pieces, 18 by 2 by 1 inch. At each end of the side pieces cut a tenon 1 inch long and 1 inch wide and one-half inch thick. Mortise them into the ends, when we shall have a frame 2 feet by 1, by 1 inch thick. Care must be taken that the mortising is done truly, and in a workmanlike manner, else when put together the sides will not be true with each other. If when glued up two of the corners are cockled, and do not lie true with the other two, if it is only slight, with a plane take off what is necessary from the opposite corners, then turn the bed over and take off as much as is needed from the corresponding corners; by this means, if there is only a slight twist, your work may be made quite true.

If you are a novice at woodwork, let me say, do nothing by guess. When your sides and ends are properly squared up, mark your tenons and mortise with a gauge, leaving your pencil mark in the wood, not cut away. You will then have a tight-fitting joint. If your sides are of the same length between the tenons when put together, the frame will be perfectly square at the angles. When we have gone so far, we can round off the sharp edge of what will be the top of the bed.

We now require two standards to carry the disks. For this purpose we shall require two pieces of wood, 10 by 6 by 1 inch; plane up and square one side and end; 1 inch from the end draw a line for tenon, and square with this a central line; you must now taper the standards, from the foot to the top. The central line will enable you to get the taper true. Fig. 1, B, will show you a desirable shape. Cut two tenons in the foot as shown by the dotted lines. The top should be rounded off as well as the edges. Draw a line across the center of the sides of the bed, put the standards perpendicular to the bed with the central line true with line drawn and mark where the tenons are to be mortised in. 8½ inches from the foot bore a one-half inch hole in each standard. Before gluing the standards in their place, see that they are perfectly true with each other, and that a rod passed through the holes will appear true with the bed when casting the eye over it. When your work is satisfactory, it can be glued together.

Out of one-half inch wood we must make eight pieces for bracket feet of somewhat triangular form; the precise form will be a matter of taste. Four of

them must be one-half inch narrower than the others. When joined at right angles to the others, the thickness of the wood will make up the deficiency. Care must be taken that these are perfectly square. If the edges are true, good glue will be sufficient to join them; if any doubts exist as to the strength of the joint, then with a one-fourth inch center bit bore a hole one-fourth inch deep, put in a screw and then plug the hole with a plug, cut with the grain running the same way with the brackets. When the brackets are perfectly true and ready for fixing, take the under side of the bed and gauge a line one-half inch from the edge along the four corners, ends, and sides; with a compass mark off a point on the top of each bracket, and a corresponding mark from the gauged line in the bed; with a center bit bore one fourth inch hole; prepare eight dowel pins, and with these and glue fix your brackets in their place; see dotted lines, Figs. 1 and 2. If your work is done properly, the bed will hang over the feet one-half inch, which will give a finished appearance to it. By an oversight I have not so shown it in the elevation, but marked the brackets flush with the bed, but the plan indicated will make a more finished job.

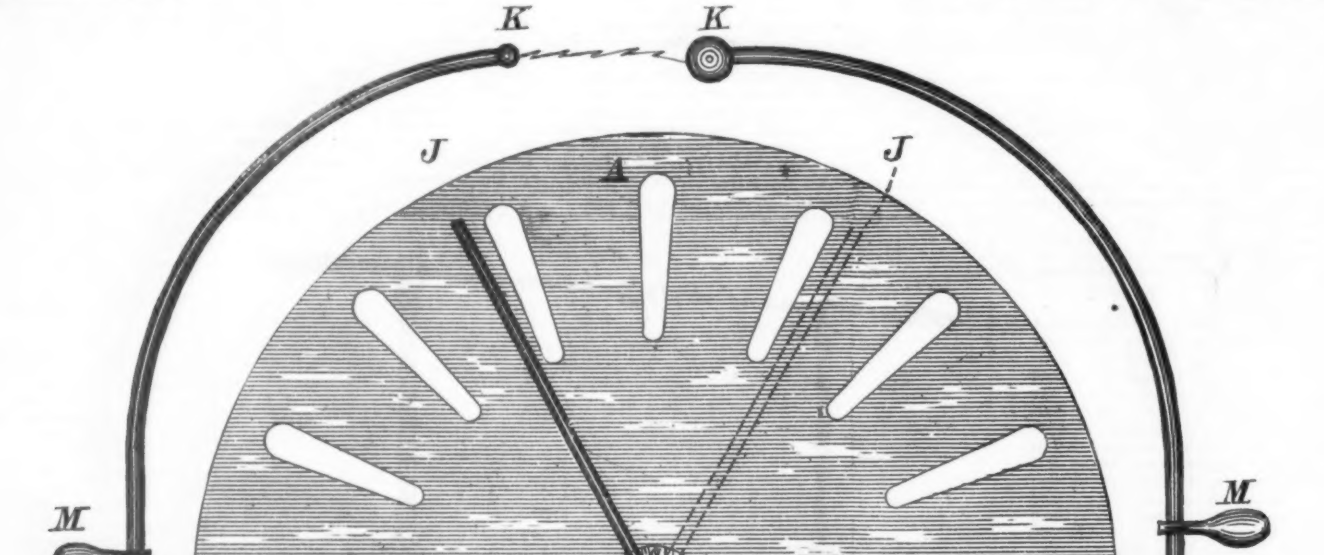
wood shall not scratch the foil on the jars. We will now proceed with the driving wheels.

Procure two pieces of mahogany 7 inches square and, say ¾ or 1 inch thick; these must be turned in a lathe with a center hole, say 2 inches in diameter, and with a groove in the circumference for the driving belt. Now procure a length of round iron or steel, ½ inch rod and 14 inches long, file the ends perfectly true, and make a center punch mark in each end in the exact center. Next take two pieces of wood, say 4 inches long and 2½ inches in diameter, bore a central hole in each longitudinally large enough to admit the rod, but they must drive on tight. Let the rod project 2 inches at one end, 4 inches at the other. The two pieces will thus meet.

Turn them down till they will permit the driving wheels being driven on tight. Cut away ½ inch of each piece in the center, leaving 1 inch of the rod clear, also turn the other end off with a bead or in any other way to make a nice finish. When turned and completed, lay it across the bed, the short projecting end of the rod being flush with the bed; the driving wheels should then be about 2½ inches from each side of the frame or bed.

the position of the groove in the driving wheels, and in an exactly corresponding position a groove must be turned in the bosses to receive the driving bands. Now pass the spindle through the standards and bosses as shown, put a band on each and the corresponding driving wheel, one band direct, the other crossed, and we shall be able to drive the disks in an opposite direction at a uniform speed.

Now for our glass disks. Of course, these can be bought with ground edges and with central hole, but we think with a little care we may be able to either make them or get them of a local glazier. First of all, cut a pattern 18 inches in diameter in thick cardboard of twelve sheet, such as is used for cutting picture mounts. Cut the central hole a trifle, say ½ inch, larger than the hole in the glass is to be; take this to a glazier and get him to select a sheet of glass perfectly flat if he has it, if not, as near flat as possible. It should be the thinnest he has, not more than $\frac{1}{16}$ inch thick, and white; this last point must not be overlooked, as the white kinds are less disposed to conduct electricity; some of the green kinds of glass can hardly be electrified. Mr. Wimshurst has given a simple test to discover if the glass is of the right quality. Take a light



THE WIMSHURST ELECTRICAL MACHINE.

One inch from the center of each end, two holes must be bored or cut ⅛ inch larger than the glass jars, which we will suppose are 2 inches in diameter. The jars, of course, must be procured first. You must now prepare two pieces 11 by 3½ by 1 inch to form shelves on which the jars must rest. Glue cleats on the inside of each bracket, so that the shelves resting on them shall be 1 inch from the bottom. When this is done, place the shelves in position, mark where the brackets come, and cut out a piece in the shelf, so that it shall come flush with the brackets. Before the shelves are fixed in their places, two cavities must be made in them the same size as the holes in the bed, but not more than about ⅛ inch deep; these are for the purpose of giving stability to the jars and also for another purpose to be referred to further on.

Perhaps some difficulty may be experienced in making the holes, as it is not likely the amateur will have a center bit the size.

Proceed thus: With a compass mark out the hole required, then with the largest center bit you have bore a ring of holes nearly up to the margin of the circle; the holes can then be completed with a gouge and rasp. The cells in the shelves can be worked out in the same way. The bottoms leveled by a chisel. When everything is done so far to your satisfaction, glue a bit of velvet on the edge of the holes and cells, so that the

If they do not stand at the same distance, they must be shifted until they do. The longest end of the rod should now be either screwed or squared off to receive a crank handle. Exactly in the center under the standards two bearings, either of wood or brass, as shown in Fig. 1, must be screwed for the driving wheels to run in. Fig. 4 gives a reduced view of driving wheels. We now require bosses to fix the glass disks in their place.

For this purpose we shall need two pieces of mahogany 4½ by 3 inches. But, first of all, we shall have to deal with a spindle for the same; for this purpose we shall require a steel rod 18 inches long and ⅜ inch in diameter. This must be perfectly true. We must also procure 6 inches of brass tubing, large enough to admit the rod easily, but not with much shake; cut it into four equal pieces. Now bore a center hole through the length of each piece of mahogany so as to admit the brass tube being driven in perfectly tight; these brasses will form bushes in the bosses to run on the steel bearing just referred to. Turn the bosses on a mandrel to a shape as shown, Fig. 5. At one end there will be a disk to receive the plate of glass with a nipple 1 inch in diameter and ¼ inch deep. We will suppose that the exact distance between the standards to carry the glass plates is 9 inches, then the combined length of these two bosses must be just $\frac{1}{16}$ inch less. Measure

body, such as a feather or small bit of paper, and fasten it to a silk thread. Now warm the glass and rub it with a silk handkerchief. If the glass is all right, the bit of paper will vigorously fly and adhere to the glass if brought near to it; if, on the other hand, the glass will not attract the body when brought, say, within an inch or two, the disk is useless for our purpose. But before we condemn it, we should be sure that the glass is dry; this can be easily assured by warming it before the fire. With the template of cardboard laid on the glass the glazier will find no difficulty in cutting a perfectly round disk. Should you attempt to do it yourself, turn the glass over and run the diamond across the four corners, so as to intersect the circle. If you are not very sure of your cut, either tap along the cut on the opposite side, so as to complete the fracture, or take a piece of hot iron and run around. A crack will follow the heat.

Now to make central hole. There are two modes, either of which we can adopt. The first is to cut a small circle by the aid of the template, and then to make cuts across at several diameters, and by one of the modes just indicated make a fracture through the glass; lay the glass on a flat tube with a smooth cloth under it, and then with a sharp point—the point of a scissors will do—tap away in a small circle until you make a hole, and then gradually take away the glass

bit by bit. I have seen a round hole made in the side of a glass bottle by the point of a scissors alone without any previous cutting, and done quickly too; but I do not think I have ever seen it recommended in any article.

There is another plan which I have recently seen recommended, which is, undoubtedly, a good one if many disks are to be perforated, but a good bit of trouble if only a couple of plates are to be made. Place the plate on a flat table, over it fix a frame with two wide bars, one above the other; a hole must be bored in each bar an inch in diameter and directly perpendicular to each other. A copper tube is now taken of a diameter to move easily in the inch holes; one end of it must be beaten up with a hammer, so that the diameter shall be slightly increased; by this means it will clear itself when going through the glass.

Fix the glass on the table so that the tube shall come exactly in the center, pour emery and water, not too thin, down the tube, and make the tube revolve with a drill fiddle-bow; the tube should be weighted with a ring of lead to keep it hard on the glass; by this means a hole is expeditiously cut in the disk. Although I have not tried it, I have no doubt it is an efficient means where large numbers are required, but for the amateur, who, perhaps, only requires a pair of plates, the first plan I have recommended is the cheaper.

If there is any slight hollow in the disks, then let the concave sides be next each other. They must now be fixed to the bosses. Any of the ordinary cements prepared for mending glass and china will do. See that the cement is very thin, with heat, also warm the boss and the disks, but be careful of the latter that you do not crack it with the heat. Now quickly cover the face of the boss with the cement, and place a ring of it around the hole in the disk. You will need some one to help you; gently but firmly press the disk up to the boss, being careful that it is set perfectly true and at right angles with the spindle. Before it is set pass the spindle through it and the standards, and by steadily and slowly revolving it, you will be able to fix it perfectly square. When one is set, then do the same by the other.

The center of the boss will come through, say, about ⅛ inch. See to it that the brass bush is hardly level with the boss, but just within. If everything is just as it should be, when the spindle is put in its place the disks will revolve just ¼ inch apart and touch at no point. The nearer they can come without coming in contact, the better.

As a further precaution against the possibility of the disks coming off, two thin rings of ebonite, with the hole made to fit tightly on the end of the bosses, may be cemented to the bosses and disks; but if proper care has been taken in making the bosses with a perfectly flat surface, and that there is perfect contact between them and the glass, with cement between, there is but little danger of the disks coming off.

The sectors of tinfoil must now claim our attention. As a matter of fact, it will be best to attend to them before the disks are cemented to their bosses. On the cardboard which we have used as a template, mark off an equal number of lines, say twenty; these must be marked off with a compass at exactly the same distance apart.

I may explain why there must be even numbers and

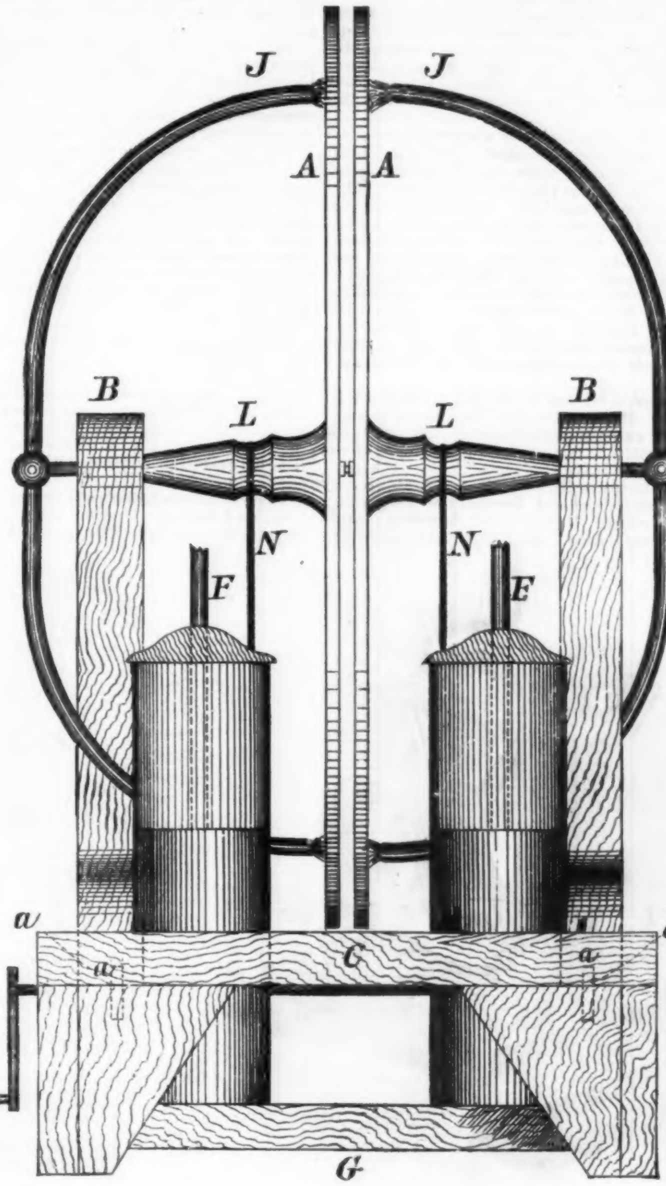


FIG. 2.—END ELEVATION.

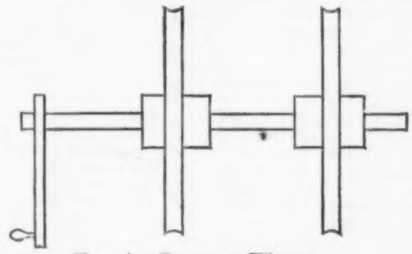


FIG. 4.—DRIVING WHEEL.

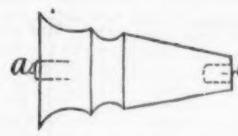


FIG. 5.—BOSS.
DOTTED LINES, a—a', SHOW BRASS BUSHES TO RUN ON SPINDLE.

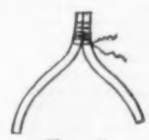


FIG. 6.—MODE OF JOINING BELT.

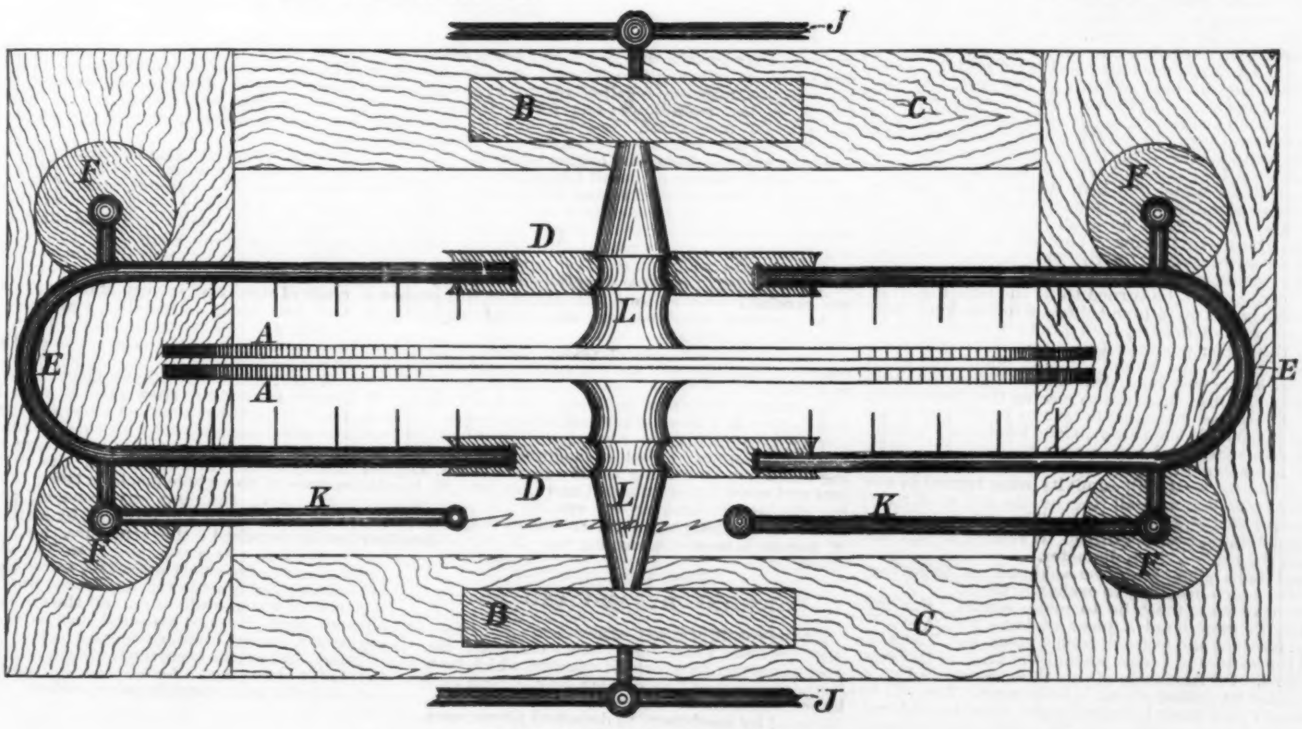


FIG. 3.—PLAN VIEWED FROM TOP.

THE WIMSHURST ELECTRICAL MACHINE.

not odd, as nineteen or twenty-five. If odd, there would be no two exactly opposite, but as the neutralizing brushes must touch two exactly at the same time, they must go in opposite pairs. Now take some tinfoil and cut out a number of wedge-shape pieces, according to the number of lines for the two disks. If you have twenty lines on each disk, then you must prepare forty segments. They should be 3¼ inches long, ¾ wide at one end and ¼ at the other; let the ends be rounded off. Put your pattern with the lines drawn in it on a flat surface, and your glass disk on it, and with strong shellac cement fix the segments of foil to the glass; let the center of each segment fall on the line; let the head of the segment be placed ½ inch from the edge of the disk.

See to it that no air bubbles are under the foil, but that it is in contact all over with the glass. One thing must be guarded against: be sure that no sharp point of foil is left on the edge, and that no corner is left sticking up; if so, the point will serve the purpose of a lightning conductor, and conduct your electricity away into space. Indeed, I would say now, and once for all, that there must not be the least sharp edge or point to any of our metal fittings, for, according to a well-known law of electricity, a sharp point will conduct away electricity, insensibly; for this reason, and not for mere ornament, it is necessary that all metal rods, etc., must terminate as spheres.

It will be best if now at this stage the disks are coated with shellac varnish, and dried quickly in a warm room or before a fire. Care must be taken that a portion of the tinfoil sectors be left unvarnished at the point where the brushes touch. As an additional precaution, give each end of the sectors an additional coat of varnish. We must next provide five brass knobs or balls, about 1½ inches diameter. Door knobs might easily be adapted for the purpose, by filing or turning away the sharp edge of the shank.

Take two pieces of tubing the same size as that used for bushing the bosses carrying the plates, and 4 inches long. In two of the balls bore a hole to receive one of the tubes; solder them in position, leaving, say, 3½ inches projecting. A ¼ inch hole must be drilled either through the knob, as shown in Figs. 1 and 2, or through the tube. Take two pieces of ¼ inch brass wire or rod of a sufficient length to come, when passed through the ball and bent either at right angles or in a curve as shown, to within ½ inch of the plates, over the point where the sectors are left free from shellac. The tubes carrying balls and rods are now placed in the standards, fitting tightly, at the same time receiving the ends of the spindle carrying the plate. By this means we shall be able to turn the neutralizing rods in any direction. The ends of the rods must have a hole bored to receive the brush, say ½ inch deep, after which the ends must be rounded. Procure a small quantity of gilt wire such as is used by lace-makers—almost any philosophical-instrument maker will keep it now, I suppose—wind ten laps around a carving-knife, and cut one edge. Carefully twist the double ends together, and push them in the ends of the rods, and fasten them by a small peg of wood; four of these brushes will be required. Make all the wires straight, and cut to the same length. Put the rods in their place, and secure neatly by a touch of solder.

When these are finished satisfactorily, turn the knobs around till the rods stand in the position indicated. The exact position will have to be determined by experiment, but as a good guide, I would give the following plan: Suppose there are twenty sectors on each plate, bring a sector at the top to stand perpendicular, then turn the front rod so that the top end stands to the left, midway between second and third sectors; turn the machine around, and place the other neutralizing rod in a similar position. They will thus cross each other at an acute angle; but by experiment you will have to determine the exact angle.

We have next to consider the Leyden jars. We will take for granted that they are 10 inches high by 2 inches in diameter. Of course, these measurements are not absolute. Take a piece of foil 6 by 4 inches, smooth out all creases, cover one side with strong paste or shellac cement, and line the inside of the jar with it, bringing it within 6 inches of the top; cut out a circular piece for the bottom inside; coat the outside in the same way, bringing the foil to a level with the inside. We now require four disks of tin plate of a size to go into the circular recesses in the shelf. In the center of each solder an inch or two of copper wire—bell wire will do; make a small hole in the center of the recess, and pass the wire through; bring the two wires in contact, and solder them; do this to each end. Now solder a long piece of wire to one end, and lead the wire along under the bed, where it will not be seen, to the other end, and solder as before. The wire can be kept in position by small staples, such as are used in fixing wire fencing. You will see that by this means the outer coating of the four jars are brought into one circuit when they are in position. Four wood bungs or caps must be turned to fit the jars, Fig. 1, F. Take four pieces of ½ inch tubing, 6 inches long, bore a hole in each of four 1½ inch knobs large enough to admit the tube; push the tube in until it touches the opposite side of the knob. At this point, the exact diameter of the first hole, drill another ¼ inch hole in two of the knobs; these are to receive the discharging rods. For these you must take two lengths of brass rod, of a size to fit the tubes in the knob—say ¼ inch. These rods must be long enough to bend at a right angle, as shown in Fig. 1, K, and to go through the ball; a handle, as M, will admit its being turned in any direction. Solder a small ring on the rod at E; this will keep it at its proper height. The end of each rod at K must be cut with a thread to receive a ball, one 1½ and the other ½ inch diameter.

These balls should not be soldered, as there may sometimes be a necessity to exchange them.

Our next work must be to make combs. For this purpose we must bend a piece of brass rod into a U-shape, long enough to reach from a point, say, 1 inch beyond the sectors to 1 inch beyond the knob of the jars, see Fig. 4. On the inside of the U, as shown in Fig. 3, holes must be drilled about ¾ inch apart; five will be sufficient; into these holes brass pins must be soldered, of such a length as will leave 1½ inches clear between the points.

Supposing the legs of the U are 2½ inches apart, they would be about ½ inch long, and ½ inch from each plate. In Fig. 3, at F, a short length of brass tubing is shown screwed and soldered into the knob; file a hollow in the projecting end to receive the comb, adjust the length of the connecting piece to take the comb, as shown in the figure, and solder firmly.

The ends of the comb must be furnished with small balls or capped with India rubber. Balls will give a better finish, but the caps are equally effective. Having made all the parts so far, place the tubes in the caps of the jars, put on the balls with the combs, and steady them by passing the discharging rods through the balls into the tubes. Adjust the tubes until the comb shall stand even and true just across the diameter of the plates. Solder a brass ring around the tube to rest on the cap; there will then be no danger of these getting displaced. Make four pieces of chain, of copper wire, long enough when fastened to the end of the tube to touch the bottom of the jars. By this means the interior of the jars become connected with each other. This will complete the mechanical part of the machine.

When we have got so far, all the woodwork must be glass-papered off, and then polished. The brasswork should be worked smooth with emery, and polished with rottenstone, and then properly lacquered. This will give us a handsome machine. A driving belt can be made of the ordinary sewing machine belt; a good way to join the belt is to cut it 1 inch longer than it will require to be made, put the ends side by side, and then, with strong thread or wire, bind them together for ½ inch; when done, the end will stand perpendicular to the belt. It will not look quite so nice as if the ends were scarfed together in the length of the belt, but in passing around the wheels this kind of joint gives no jerk, which an ordinary scarf would be sure to do.

We must now look over our work and see that everything is in order. If the disks are too close, place a ring of cardboard well varnished between them; if too far apart, then, with a rasp, take away a little of the projecting part of the boss.

Now a word as to quantities: Mahogany, 3½ feet by 14 inch by 1 inch; steel rod for spindle for disks, 1 foot; ditto for driving wheel, 1 foot 3 inches; brass tubing, 2 feet; brass wire for discharges and neutralizing rods, four lengths of 2 feet each; brass balls, seven large ones as follows: two for disk spindle, one each Leyden jars, and one for discharger. Five small ones 1 inch or less as follows: one for each end of comb and one for discharger. Leaving out the glass disks and tinfoil, one can see approximately what such a machine will cost before he begins his work.

One small matter of detail I have overlooked. Fill the end of the tube carrying the ball, in connection with the two front Leyden jars, with sound cork, and make a central hole to receive the ends of the discharging rods, which, when passed through the balls and into cork, will be firm, and yet may be easily moved to right or left. If these directions in all their details are carefully worked out, the amateur will possess a very excellent machine, and one capable of giving at least a six inch spark.

Figs. 1, 2, 3, show side elevation, end elevation, and plan of machine, and are drawn on a scale of 4 inches to a foot.

References to letters in Figs. 1, 2, 3.—A, disks; B, standards; *a*, V piece taken out of head of each standard to give facility in replacing disks, the V piece is kept in by screws; C, belt of machine; *a*, dowels holding brackets; D, driving wheel; E, combs; F, Leyden jars and wood bung; G, shelf carrying jars; H, handle for driving; I, bearing for spindle; J, neutralizing rods; K, discharging rods; L, bosses carrying disks; M, handle to move discharging rod; N, belt.—*Amateur Work.*

ENGINE DYNAMO AND MOTOR.

As the result of many experiments and trials extending over some years, on dynamo machines, Mr. Henry Joel has designed a form of dynamo which he terms an "engine dynamo," and which may be seen represented in our illustrations. It is so named from its being manufactured by machinery in detached pieces, each of perfected mechanical construction, and it is contended for this form that, owing to the many improvements in its mechanical and electrical construction, it shows a marked superiority over the ordinary types of dynamos.

It has been usually the case, when an accident has happened to a dynamo, such as the shunt-circuiting of a portion of the armature, damage to field magnets, commutators, or many other faults which may at any time happen to place a machine, for the time, *hors de combat*, that it has been necessary to forward the *whole* machine to the works in order that only a single part may be repaired. In the machine now before us, which was shown at work at the Inventions Exhibition last year, the various parts are made unusually strong and most carefully exact, and every machine is made of detachable parts which are interchangeable. Blakey, Emmott & Co., London, are the manufacturers.

Fig. 1 shows the dynamo with its adjustable bed-plate and screw-tightening gear; two pulleys (fast and loose) are also shown for driving purposes. The two field magnets are vertical, with massive cores of soft wrought iron carefully annealed, and are of extremely simple form, united above and below by yokes of selected cast iron, which are specially formed so as to serve also as pole pieces. The field magnet coils are not, as usual, wound direct on to the iron cores, but are wound on to a bobbin fitting the cores, so that in case of any damage to the wires they can be easily taken off and repaired, without the removal of the magnets and similar heavy trouble. The pole pieces have their under faces grooved so as to break up eddy currents, and accumulate the magnetic effects as much as possible at the center of the poles, rendering the magnetic field as strong as possible.

The armature, which is shown in Fig. 2, is a modified Pacinotti ring, and is built up of interlocking segments bolted together. These segments may be seen in Fig. 3; they consist of laminated Swedish iron plates punched with the tooth-shaped projection alternately at one end; these thin plates are insulated from each other except at the junctions of the sections, where iron is pressed in contact with iron to form a series of continuous rings.

The sections when complete are made to fit and interlock, and they are secured with insulated bolts of non-magnetic material. They form when built up in this manner the outer rim of the ring armature, as seen. The coils for the armature are specially wound to exact size in detachable portions, and slipped or threaded into the core sections; they can, therefore, be easily removed in case of any of them being damaged.

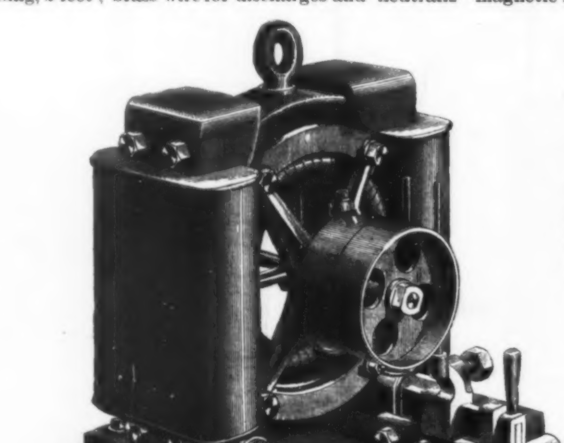


FIG. 1.—JOEL'S ENGINE DYNAMO AND MOTOR.

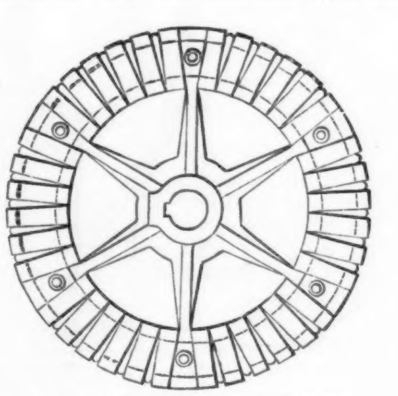


FIG. 2.—DIAPHRAGM OF ARMATURE.

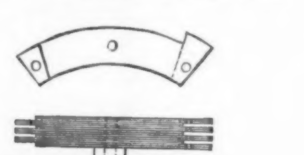


FIG. 3.—ELEVATION AND PLAN OF CORE SECTION.

ENGINE DYNAMO AND MOTOR.

The commutator and brushes being on the opposite side of the machine cannot be seen, but it may be stated that the arrangement of the commutator is special; it is fixed close to the armature coils, and the connection between the ends of the coils and the commutator bars is so made that the joints are without solder, and can be easily disconnected and reconnected. The brushes are fixed on the end of the axle (which is made of steel, and is very short with a long bearing), and are easily adjustable, but little trouble being required to remove them from contact with the commutator, or when in contact to keep them clamped in the same position.

Experiments which have been made with these machines show that they possess very high efficiency, results which have been confirmed in practical use, but the advantages claimed for this dynamo specially are the perfected manner of manufacture and the changeability of the various parts of the machine, in consequence of the whole machine being built up of detachable parts, enabling any damaged portion to be at once withdrawn and replaced by a spare section or be easily repaired; the armature, for instance, can be easily taken to pieces, and as easily put together again; the coils of the field magnets can be changed for coils giving higher or lower resistance, but from the exactness of the manufacture, and the strength of the various parts, it is not expected that parts will get out of order, except from accidents which at times may happen, and on the occurrence of such an event the replacement of the part affected can be easily accomplished with the least possible delay.—*Mech. World.*

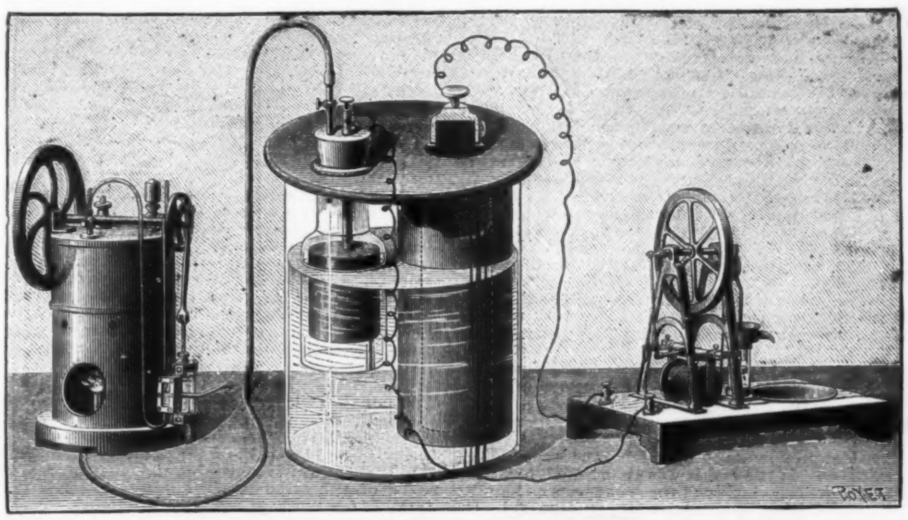
THE thinking man is the one who succeeds in life. Who calmly thinks the matter over to the end before he adopts any course which at first thought may look attractive.

TRANSFORMATION OF PHYSICAL FORCES.

ONE of our readers communicates to us an arrangement of the Bunsen battery by means of which he performs a very curious experiment on the transformation of physical forces. The annexed figure shows the general arrangement. The pile is constructed as follows: The zinc, instead of being tubular and surrounding the porous cup, is a solid cylinder, and is suspended beneath a bell glass, which is itself fixed to a wooden cover that hermetically closes the vessel through the intermedium of wax or cement. The bell glass is closed by a rubber stopper provided with two tubulures. One of these latter gives passage to the copper rod which supports the zinc, and which serves as an electrode, while the other is provided with a tube and cock that gives exit to the hydrogen gas formed. The cock, when opened or closed, opens or closes the circuit. In effect, in the first case, the hydrogen escapes, and, in the second, having no exit, it accumulates in the bell and expels the liquid. The pile then ceases to work, as the zinc is no longer immersed.

The carbon and the porous cup containing the acid are arranged alongside of the bell in the usual manner. The experiment that this pile permits of performing is as follows: The metallic conductors fixed to the two poles are connected with a small electric motor, which operates as soon as a contact is established. The disengaged hydrogen is led by means of a rubber tube beneath the boiler of a small steam engine, and, when lighted, soon boils the water and sets the engine running.

We thus have at the same time a generator of heat and electricity. This is a pretty lecture experiment, and we recommend it to physicists.—*La Nature.*



TRANSFORMATION OF PHYSICAL FORCES.

THE PHYSICAL LABORATORY IN MODERN EDUCATION.*

By HENRY A. ROWLAND, Ph.D., Professor of Physics, Johns Hopkins University.

FROM the moment we are born into this world down to the day when we leave it, we are called upon every moment to exercise our judgment with respect to matters pertaining to our welfare. While nature has supplied us with instincts which take the place of reason in our infancy, and which form the basis of action in very many persons through life, yet more and more as the world progresses and as we depart from the age of childhood, we are forced to discriminate between right and wrong, between truth and falsehood. No longer can we shelter ourselves behind those in authority over us, but we must come to the front and each one decide for himself what to believe and how to act in the daily routine and the emergencies of life. This is not given to us as a duty which we can neglect, if we please, but it is that which every man or woman, consciously or unconsciously, must go through with.

Most persons cut this Gordian knot, which they cannot untangle, by accepting the opinions which have been taught them and which appear correct to their particular circle of friends and associates; others take the opposite extreme, and, with intellectual arrogance, seek to build up their opinions and beliefs from the very foundation, individually and alone, without help from others. Intermediate between these two extremes comes the man with full respect for the opinions of those around him, and yet with such discrimination that he sees a chance of error in all, and most of all in himself. He has a longing for the truth, and is willing to test himself, to test others, and to test nature until he finds it. He has the courage of his opinions when thus carefully formed, and is then, but not till then, willing to stand before the world, and proclaim what he considers the truth. Like Galileo and Copernicus he inaugurates a new era in science, or like Luther in the religious belief of mankind. He neither shrinks within himself at the thought of having an opinion of his own, nor yet believes it to be the only one worth considering in the world; he is neither crushed with intellectual humility, nor yet exalted with intellectual pride; he sees that the problems of nature and society can be solved, and yet he knows that this can only come about by the combined intellect of the world acting through ages of time, and that he, though his intellect were that of Newton, can, at best, do very little toward it. Knowing this, he seeks all the aids in his power to ascertain the truth, and if he, through either ambition or love of truth, wishes to impress his opinions on the world, he first takes care to have them correct. Above all, he is willing to abstain from having opinions on subjects of which he knows nothing.

It is the province of modern education to form such a mind while at the same time giving to it enough knowledge to have a broad outlook over the world of science, art, and letters. Time will not permit me to discuss the subject of education in general, and, indeed, I would be transgressing the principles above laid down if I should attempt it. I shall only call attention at this present time to the place of the laboratory in modern education. I have often had a great desire to know the state of mind of the more eminent of mankind before modern science changed the world to its present condition and exercised its influence on all departments of knowledge and speculation. But I have failed to picture to myself clearly such a mind, while, at the same time, the study of human nature, as it exists at present, shows me much that I suppose to be in common with it. As far as I can see, the unscientific mind differs from the scientific in this, that it is willing to accept and make statements of which it has no clear conception to begin with and of whose truth it is not assured. It is an irresponsible state of mind, without clearness of conception, where the connection between the thought and its object is of the vaguest description. It is the state of mind where opinions are given and accepted without ever being subjected to rigid tests, and it may have some connection with that state of mind where everything has a personal aspect and we are guided by feelings rather than reason.

When, by education, we attempt to correct these faults, it is necessary that we have some standard of absolute truth; we bring the mind in direct contact with it, and let it be convinced of its errors again and again. We may state, like the philosophers who lived before Galileo, that large bodies fall faster than small ones, but when we see them strike the ground together we know that our previous opinion was false, and we learn that even the intellect of an Aristotle may be mistaken. Thus we are taught care in the formation of our opinions, and find that the unguided human mind goes astray almost without fail. We must correct it constantly and convince it of error over and over again until it discovers the proper method of reasoning, which will surely accord with the truth in whatever conclusions it may reach. There is, however, danger in this process that the mind may become over cautious, and thus present a weakness when brought in contact with an unscrupulous person who cares little for truth and a great deal for effect. But, if we believe in the maxim that truth will prevail, and consider it the duty of all educated men to aid its progress, the kind of mind which I describe is the proper one to foster by education. Let the student be brought face to face with nature; let him exercise his reason with respect to the simplest physical phenomenon, and then, in the laboratory, put his opinions to the test; the result is invariably humility, for he finds that nature has laws which must be discovered by labor and toil, and not by wild flights of the imagination and scintillations of so-called genius.

Those who have studied the present state of education in the schools and colleges tell us that most subjects, including the sciences, are taught as an exercise to the memory. I myself have witnessed the melancholy sight in a fashionable school for young ladies of those who were born to be intellectual beings reciting page after page from memory, without any effort being made to discover whether they understand the subject or not. There are even many schools, so called, where the subject of physics or natural philosophy itself is taught, without even a class experiment to illustrate the subject and connect the words with ideas. Words, mere words, are taught, and a state of mind far different from that above described is produced. If one were required to find a system of education which would the most surely and certainly disgust the student with any subject, I can conceive of none which would do this more quickly than this method, where he is forced to learn what he does not understand. It is said of the great Faraday that he never could understand any scientific experiment thoroughly until he had not only seen it performed by others, but had performed it himself. Shall we then expect children and youth to do what Faraday could not do? A thousand times better never teach the subject at all.

Tastes differ, but we may safely say that every subject of study which is thoroughly understood is a pleasure to the student. The healthy mind, as well as the healthy body, craves exercise, and the school room or the lecture room should be a source of positive enjoyment to those who enter it. Above all, the study of nature, from the magnificent universe, across which light itself, at the rate of 186,000 miles per second, cannot go in less than hundreds of years, down to the atom of which millions are required to build up the smallest microscopic object, should be the most interesting subject brought to the notice of the student.

Some are born blind to the beauties of the world around them, some have their tastes better developed in other directions, and some have minds incapable of ever understanding the simplest natural phenomenon; but there is also a large class of students who have at least ordinary powers and ordinary tastes for scientific pursuits; to train the powers of observation and classification let them study natural history, not only from books, but from prepared specimens or directly from nature; to give care in experiment and convince them that nature forgives no error, let them enter the chemical laboratory; to train them in exact and logical powers of reasoning, let them study mathematics; but to combine all this training in one, and exhibit to their minds the most perfect and systematic method of discovering the exact laws of nature, let them study physics and astronomy, where observation, common sense, and mathematics go hand in hand. The object of education is not only to produce a man who *knows*, but one who *does;* who makes his mark in the struggle of life, and succeeds well in whatever he undertakes; who can solve the problems of nature and of humanity as they arise, and who, when he knows he is right, can boldly convince the world of the fact. Men of action are needed as well as men of thought.

There is no doubt in my mind that this is the point in when much of our modern education fails. Why is it? I answer that the memory alone is trained and the reason and judgment are used merely to refer matters to some authority who is considered final, and, worse than all, they are not trained to apply their knowledge constantly. To produce men of action, they must be trained in action. If the languages be studied, they must be made to translate from one language to the other until they have perfect facility in the process. If mathematics be studied, they must work problems, more problems, and problems again, until they have the use of what they know. If they study the sciences, they must enter the laboratory and stand face to face with nature; they must learn to test their knowledge constantly, and thus see for themselves the sad results of vague speculation; they must learn by direct experiment that there is such a thing in the world as truth, and that their own mind is most liable to error. They must try experiment after experiment and work problem after problem until they become men of action, and not of theory.

This, then, is the use of the laboratory in general education, to train the mind in right modes of thought by constantly bringing it in contact with absolute truth, and to give it a pleasant and profitable method of exercise which will call all its powers of reason and imagination into play. Its use in the special training of scientists needs no remark, for it is well known that it is absolutely essential. The only question is whether the education of specialists in science is worth undertaking at all, and of these I have only to consider natural philosophers or physicists. I might point to the world around me, to the steam engine, to labor-saving machinery, to the telegraph, to all those inventions which make the present age the "Age of Electricity," and let that be my answer. Nobody could gainsay that the answer would be complete, for all are benefited by these applications of science, and he would be considered absurd who did not recognize their value. These follow in the train of physics, but they are not physics; the cultivation of physics brings them, and always will bring them, for the selfishness of mankind can always be relied upon to turn all things to profit. But in the education pertaining to a university we look for other results. The special physicist trained there must be taught to cultivate his science for its own sake. He must go forth into the world with enthusiasm for it, and try to draw others into an appreciation of it, doing his part to convince the world that the study of nature is one of the most noble of pursuits, that there are other things worthy of the attention of mankind besides the pursuit of wealth. He must push forward and do what he can, according to his ability, to further the progress of his science.

Thus does the university, from its physical laboratory, send forth into the world the trained physicist to advance his science and to carry to other colleges and technical schools his enthusiasm and knowledge. Thus the whole country is educated in the subject, and others are taught to devote their lives to its pursuit, while some make the applications to the ordinary pursuits of life that are appreciated by all.

But for myself I value in a scientific mind most of all that love of truth, that care in its pursuit, and that humility of mind which makes the possiblity of error always present more than any other quality. This is the mind which has built up modern science to its present perfection, which has laid one stone upon the other with such care that it to-day offers to the world the most complete monument to human reason. This is the mind which is destined to govern the world in the future, and to solve problems pertaining to politics and humanity as well as to inanimate nature.

It is the only mind which appreciates the imperfections of the human reason, and is thus careful to guard against them. It is the only mind that values the truth as it should be valued, and ignores all personal feeling in its pursuit. And this is the mind the physical laboratory is built to cultivate.

* Anniversary address, April, 1886.

THEORY OF THE COLOR SENSE.

AT a recent meeting of the Physiological Society, Berlin, Dr. Wolffberg spoke on the Young-Helmholtz theory of the color sense, which he extended in the direction of assuming the existence of red-sensitive, green and violet sensitive ganglia in the central organ of sight perception in the sphere of vision. These ganglia were connected with the red nerves, the green nerves, and the violet nerves, and by means of such nerves communicated with the retina. Seeing, however, that yellow, blue, and white were likewise psychically simple sensations, Dr. Wolffberg assumed specific ganglia for these as well, which, however, stood in connection with the red, green, and violet ganglia, the yellow ganglia being situated at an equal remove from the red and green, but at a further remove from the violet ganglia. Similar was his conception of the situation and connection of the blue and white ganglia. Regarding the sensation of black, he would speak in an address in the immediate future.

Dr. Uhthoff made further communications respecting

the dependence of visual sharpness on the intensity of illumination. After an historical survey of the older experiments to determine the relation of visual sharpness to light intensity, he described the results of his own labors in this field. In the case of white light, he had communicated the relation on a former occasion (*Nature*, vol. xxxi., p. 476). In the case of yellow light, the visual sharpness under low intensities increased just as rapidly with increasing intensity of light as in the case of white light. The curve, however, in the former case attained a greater height than it did with white, and then likewise proceeded parallel to the abscissa. With red light, on the other hand, the curve kept below the height reached with white light; it rose slower, moreover, and never became parallel. The curve of visual sharpness for green light lay still deeper than for red, and also rose persistently, though slowly. The curve for blue light lay deepest of all, and very soon became parallel to the abscissa of the light intensity. In the case of a green-blind person, the curves for white, yellow, and red were the same as in the case of the normal eye, as there was likewise a coincidence for blue. The curve for green fell almost coincident with the low curve for blue.

TELESCOPIC OBJECTIVES AND MIRRORS: THEIR PREPARATION AND TESTING.*

By HOWARD GRUBB.

IT would probably lend an additional interest to a technical subject such as I have to bring before you tonight, could I preface my description of the processes now employed in the construction of telescopic objectives by a short historical account of what has been attempted and achieved in the past, but time will not permit.

A very few words, however, on the history of glass manufacture are necessary.

As I pointed out last Saturday afternoon, Dollond's brilliant discovery, which afforded a means of achromatizing objectives, rendered possible their construction of greater size and perfection than formerly, provided suitable material could be obtained. But the chromatic errors being removed, faults in the material hitherto masked by them were detected, and it was not until after many years that Guinand, a lowly but gifted Swiss peasant, succeeded in producing glass disks of a considerable size and free from these defects.

The secrets of his process have been handed down in his own family to M. Feil, of Paris (one of his descendants), and also through M. Bontemps, who for a time was associated with Guinand's son, and afterward accepted an invitation from Messrs. Chance Bros. and Co., of Birmingham, to assist them in an endeavor to improve that branch of their manufacture. Only these two houses, so far as I am aware, have succeeded in manufacturing optical disks of large size.

Testing of Optical Glass.—Let me here say a few words respecting the testing of optical glass; I mean of the material of the glass, quite apart from the optician's work in forming it into an objective. When received from the glass manufacturer it is sometimes in this state, roughly polished on both sides, and sometimes in this, in which as you see there are small windows only, facets as they are called, polished on the edges. In case of lenses for telescopic objectives, it is always well to have them roughly polished on the sides, to avoid the chance of having to throw away a lens after much trouble and labor has been spent on it.

There are only three distinct points to be looked to in the testing of optical glass: (1) general clearness and freedom from air-bubbles, specks, pieces of "dead metal," etc.; (2) homogeneity; (3) annealing.

The first is the least important, and needs no instructions for detection of defects; any one can see these. The second is much more important and much more difficult to test.

The best test for homogeneity is one somewhat equivalent to Foucault's test for figure of concave mirrors.

The disk of glass should be either ground and polished to form a convex lens, or, if that be not convenient, it should be placed in juxtaposition with a convex lens of similar or larger size, and whose excellence has been established by previous experience.

The lens or disk is then placed opposite some small brilliant light (a small gas flame generally suffices), and at such a distance that a conjugate focus is formed at other side and at a convenient distance. When the exact position of this focus is found, the eye is placed as nearly as possible so that the image of flame is formed on the pupil. On looking at it with the eye in this position, the whole lens should appear to be "full of light;" but at the slightest movement to one side the light will disappear and the lens appear quite dark. If the eye be now passed slowly backward and forward between the position showing light and darkness, any irregularity of density will be most easily seen.

Of course, like everything else, some experience is necessary.

The *rationale* of this is very obvious. When the eye is placed exactly at the focus of a perfect lens, the image formed on the pupil is very small, and the slightest movement of the eye will cause the light to appear and disappear. If the eye be not at the focus, the pencil of light will be larger, and consequently it will require a much greater movement of the eye to cause the light to disappear. Now, if any portion of the lens be of a different density to the general mass, that portion will have a longer or a shorter focus; consequently, while the light flashes off the general area of the lens quickly, it still remains on the defective portions.

By imitating this arrangement, and substituting a camera for the eye, and forming the focus of a small point of light on the stop of the lens, I have succeeded in photographing veins in glass, and sometimes have found this useful as a record.

The third point—that of proper annealing—is easily tested by the polariscope.

For small disks, the usual plan is to hold them between the eye and a polarizing plane, such as a piece of glass blackened at back or a japanned surface, and look at them through the facets, using as an analyzer a Nicol prism.

Larger sizes, which are polished on the surfaces, can be more easily examined. It is difficult to describe the appearances, but I will put a few disks into the lantern polariscope, and endeavor to point out what amount of polarization may safely be permitted in disks of glass to be used for objectives.

The composition of metallic mirrors of the present day differs very little from that used by Sir Isaac Newton. Many and different alloys have been suggested, some including silver or nickel or arsenic; but there is little doubt that the best alloy, taking all things into account, is made with 4 atoms of copper and 1 of tin, which gives the following proportions by weight: copper 252, tin 117·8.

Calculation of Curves.—Having now obtained the proper material to work upon, the first thing necessary is to calculate the curves to give to the lenses, in order that the objective, when finished, may be of the required focus, and be properly corrected for the chromatic and spherical aberrations.

As this lecture is intended to deal principally with the technical details of the process, I do not intend to occupy your time for more than a few moments on this head, nor indeed is it at all necessary. In my lecture last Saturday I explained the principles of achromatism, and in many published works full and complete particulars are given as to the calculation of the curves—particulars which are sufficient, and more than sufficient, for the purpose.

Much has been discussed and written concerning the calculation of curves of objectives, and much care and thought has been bestowed by mathematicians on this subject, and, so far as the actual constructors are concerned, a certain amount of veil is thrown over this part of the undertaking, as if there were a secret involved, and as if each had discovered some wonderful formulæ by which he was enabled to calculate the curves much more accurately than others.

I am sorry to have to dispel this illusion. Practically the case stands thus. The calculation of the curves which satisfy the conditions of achromatism and desired focus is a most simple one, and can be performed by any one having a very slight algebraical knowledge in a few minutes, provided the refractive indices and dispersive power of the glass be known. Both Messrs. Chance and Feil supply these data quite sufficiently accurately for small size objectives. Speaking for myself, I am quite content to take the figures as given by these glass manufacturers for any disk up to 10 inches in diameter. If over that size, I grind and polish facets on the disk and measure the refractive and dispersive powers myself.

The calculations of the curves required to satisfy the conditions of spherical aberration are very troublesome, but fortunately these may be generally neglected.

Some years ago the Royal Society commissioned one of its members to draw up tables for the use of opticians giving the curves required to satisfy the conditions of both corrections for all refractive and dispersive indices.

A considerable amount of labor was expended on this work, but in the end it was abandoned, for it was found that the calculation of these curves was founded on the supposition that all surfaces produced by the opticians were truly spherical; while the fact is, a truly spherical curve is the exception, not the rule. The slightest variation in the form or figure of the curve will produce an enormous variation in the correction for spherical aberration, and it was soon apparent that the final correction for spherical aberration must be left to the optician, and not to the mathematician. *Object glasses cannot be made on paper.* When I tell you that a sensible difference in correction for spherical aberration can be made by half an hour's polishing, corresponding probably to a difference in the first place of decimals in radii of the curves, you will see that it is practically not necessary to enter upon any calculation for spherical aberration. We know about what form gives an approximate correction. We adhere nearly to that, and the rest is done by figuring of the surface.

To illustrate what I mean: I would be quite willing to undertake to alter the curves of the crown or flint lens of any of my objectives by a very large quantity, increasing one and decreasing the other so as to still satisfy the conditions of achromatism, but introducing theoretically a large amount of positive or negative spherical aberration, and yet to make out of the altered lens an object glass perfectly corrected for spherical aberration.

I am now speaking of ordinary sizes. For very large sizes it is usual to go more closely into the calculations; but I may remark that it is sometimes possible to make a better objective by deviating from the curves which give a true correction for spherical aberration, and correcting that aberration by figuring, rather than if the strictly theoretical curves were adhered to. So far, then, as any calculation is required, the ordinary formulæ given in the text-books may be considered amply sufficient.

Having now determined on the curves, we have to consider the various processes which the glass has to undergo from the time it is received in this form from the glass manufacturer to the time when it is turned out a finished objective.

The work divides itself into five distinct operations: (1) rough grinding; (2) fine grinding; (3) polishing; (4) centering; (5) figuring and testing.

(1) The rough grinding or approximate shaping of the glass is a very simple process. The glass is cemented on a holder, and is held against a revolving tool supplied with sand and water, and of a shape which will tend to abrade whatever portions are necessary to be removed to produce the required curves. These diagrams will illustrate the various operations.

(2) Fine grinding. The tools used for fine grinding are of this form, and are made of either brass or cast iron. I prefer cast iron, except for very small sizes. They are grooved on the face, in the manner suggested by the late Mr. A. Ross, in order to allow the grinding material to properly distribute itself.

If two spherical surfaces be rubbed together, they will, as may be supposed, tend to keep spherical; for the spherical is the only curve which is the same radius every part of its surface. If fine dry abrading powder be used between, the same result will be obtained; but if wet powder be used, the surface will no longer continue spherical, but will abrade away more on the center and edge than in the zone between. It was to meet this difficulty that the late Mr. A. Ross devised the idea of the distributing grooves. The fine grinding process is the first of the series which calls for any skill on the part of the operator.

That the *modus operandi* of the grinding be the more easily understood, let me explain the principle of the process in a few words.

When two surfaces of unequal hardness are rubbed together, with emery powder and water between the two, each little particle of the powder is at any given moment in either of these conditions: (*a*) embedded into the softer surface; (*b*) rolling between the two surfaces; (*c*) sliding between the two surfaces.

Those particles which become embedded in the softer material do no work in abrading it, and but little in abrading the harder. They generally consist of the finer particles, and are kept out of action by the coarser which are rolling or sliding between the surfaces. Further, those that are purely rolling do little or no work. The greater part of the work is performed by those particles which are faceted, and which *slide* between the two surfaces.

As the grinder is always of a much softer material than the glass, there is much more friction between the grinder and these particles than between the glass and the same particles, and therefore they partially adhere to the grinder and are carried by it across the face of the glass. This being so, it is now easy to perceive what the best conditions for rapid grinding are. Not too little emery, for then there will not be enough of abrading particles; not too much, for then the particles will roll on each other, and tend to crush and disintegrate each other instead of abrading the glass, but just sufficient to form a single layer of particles between the grinder and the glass surface.

In the grinding of the small lenses, I mean up to 5 or 6 inches diameter, it is usual to carry out the entire grinding processes by hand; above that size, by machinery. Surfaces up to 12 or even 15 inches can be ground by hand; but the labor becomes severe, and for my part I am gradually reducing the size for which the hand grinding is used, as I find the machine work more constant in its effects.

The machinery used is the same as that employed for the polishing operation, and I shall describe it under that head further on.

In the fine grinding operation by hand, the glass is usually cemented on to a holder of this form, having (for smaller sizes) three pieces of cork, to which the lens is attached, and this holder being screwed to a spud or nose on top of a post screwed to the floor. The operator, having applied the proper quantity of moist emery powder between the grinder and the glass, proceeds to work the former over the latter in a set of peculiar strokes, the amplitude and character of which he varies according to circumstances, at the same time that he changes his position round the post every few seconds. . . .

Although, as I have shown, the harder material is abraded very much more than the softer, yet the softer (the grinder) suffers considerable abrasion as well as the glass, and the skill of the operator is shown by the facility with which he is able to bring the glass to the curve of the grinder without altering the curve or figure of the latter.

It is even possible for a skilled operator to take a lens of one curve and a grinder of, say, a deeper curve, and by manipulation to produce a pair of surfaces fitting together, and of shallower curves than either.

Measurement of the Curves.—In the early stages of grinding, gauges of the proper radius, cut out of sheet brass or sheet steel, are used for roughly testing the curves of the lenses; but when we get to the finer grinding process, it is necessary to have something much more accurate.

For this purpose a spherometer is used. It is made in various forms, generally with three legs terminating in three hardened steel points, which lie on the glass, and a central screw with fine thread, the point of which can be brought down to bear on the center of the glass. In this way the versed sine of the curve for a chord equal to diameter of circle formed by these points is measured, and the radius of curve can be easily calculated from this.

I do not find the points satisfactory for regular work. They are apt to get injured or worn, and for ground surfaces are a little uncertain, as one or other of the feet may find its way into a deep pit. This particular spherometer has three feet, of about half an inch long, which are hardened steel knife-edges forming three portions of an entire circle. In using this it is laid on the surface to be measured, and the screw with micrometer head is turned till the point is felt to touch the surface of glass. This scale and head can then be read off. The screw in this instrument has fifty threads to the inch, and the head is divided into 100 parts, so that each division is equal to $\frac{1}{5000}$ of an inch. With a little practice it is easy to get determinate measures to $\frac{1}{10}$ of this, or $\frac{1}{50000}$ of an inch; and by adopting special precautions even more delicate measures can be taken, as far probably as $\frac{1}{100000}$ or $\frac{1}{150000}$ of an inch, which I have found to be practically the limit of accuracy of mechanical contact.

To give an idea of the delicacy of the instrument, I bring the screw first into contact with the glass. Now the screw is in good contact; but there is so much weight still on the three feet that, if I attempt to turn it round, the friction on the feet opposes me, and it will not stir except I apply such force as will cause the whole instrument to slide bodily on the glass. Now, however, I raise the whole instrument, taking care that my hands touch none of the metal work, and that the screw be not disturbed. I lay my hands for a moment on part of the glass where center screw stood, and thus raise its temperature slightly, and on laying the spherometer back in the same place, you now see that it spins on the center screw, showing how easily it detects what to it is a large lump, caused by expansion of the glass from the momentary contact of my hand.

Flexure.—One of the greatest difficulties to be contended with in the polishing of large lenses is that of flexure during the process.

It may appear strange that in disks of glass of such considerable thickness as are used for objectives, any such difficulty should occur; but a simple experiment will demonstrate the ease with which such pieces of glass can be bent, even under such slight strain as their own weight.

We again take our spherometer, and set it upon a polished surface of a disk of glass of about 7½ inches diameter and ¾ inch thick. I set the micrometer head as in the former experiment to bear on the glass, but

* Lecture given at the Royal Institution on Friday, April 2, 1886, by Mr. Howard Grubb F.R.S., F.R.A.S.

not sufficiently tight to allow the instrument to spin round. This has now been done while the glass, as you see, is supported on three blocks near its periphery. I now place one block under the center of disk and remove the others thus, and you see the instrument now spins round on center screw.

It is thus evident that not only is this strong plate of glass bending under its own weight, but it is bending a quantity easily measurable by this instrument, which, as I shall presently show, is quite too coarse to measure such quantities as we have to deal with in figuring objectives.

After this experiment no surprise will be felt when I say that it is necessary to take very special precautions in the supporting of disks during the process of polishing, to prevent danger of flexure; of course, if the disks are polished while in a state of flexure, the resulting surface will not be true when the cause of flexure is removed.

For small-sized lenses no very special precautions are necessary, but for all sizes over 4 inches in diameter I use the equilibrated levers devised by my father, and utilized for the first time on a large scale in supporting the 6 foot mirror of Lord Rosse's telescope. These have been elsewhere frequently described, but I have a small set here as an example.

I have also sometimes polished lenses while floating on mercury. This gives a very beautiful support, but it is not so convenient, as it is difficult to keep the disk sufficiently steady while the polishing operation is in progress without introducing other chances of strain.

So far I have spoken of strain or flexure during the process of working the surface; but even if the surface be finished absolutely perfectly, it is evident from the experiment I showed you that very large lenses when placed in their cells must suffer considerable flexure from their own weight alone, as they cannot then be supported anywhere except round the edge.

To meet this I proposed many years ago to have the means of hermetically sealing the tube, and introducing air at slight pressure to form an elastic support for the objective, the pressure to be regulated by an automatic arrangement according to the altitude. My attention was directed to this matter very pointedly a few years ago from being obliged to use for the Vienna 27 inch objective a crown lens which was, according to ordinary rules, much too thin.

I had waited some years for this disk, and none thicker could be obtained at the time. This disk was very pure and homogeneous, but so thin that, if offered to me in the first instance, I would certainly have rejected it. Great care was taken to avoid flexure in the working, but, to my great surprise, I found no difficulty whatever with it in this respect. This led me to investigate the matter, with the following curious results:

If we call f the flexure for any given thickness, t, and f' the flexure for any other thickness, t', then $\frac{f}{f'} = \frac{t^3}{t'^3}$ for any given load or weight approximately. But as the weight increases directly as the thickness, the flexure of the disks due to their own weight, which is what we want to know, may be expressed as $\frac{f}{f'} = \frac{t}{t'}$.

Let us now consider the effect of this flexure on the image. In any lens bent by its own weight, whatever part of its surface is made more or less convex or concave by the bending has a corresponding part bent in the opposite direction on the other surface, which tends to correct the error produced by the first surface. This is one reason why reflectors which have not this second correcting surface are so much more liable to show strain than refractors. If the lens were infinitely thin, moderate flexure would have no effect on the image. The effect increases directly as the thickness. If then the flexure, as I have shown, decreases directly as the thickness, and the effect of that flexure increases directly as the thickness, it is clear that the effect of flexure of any lens due to its own weight will be the same for all thicknesses; in other words, no advantage is gained by additional thickness.

This has reference, of course, only to flexure of the lens in its cell after it has been duly perfected, and has nothing to do with the extra difficulty of supporting a thin lens during the grinding and polishing processes.

Polishing.—The polishing process can be, and is often, conducted precisely in the same manner as the grinding, except that the abrading powders used (oxide of iron, rouge, an oxide of tin, putty powder) is of a finer and softer description, and the surface of the polishing tool is made of a softer material than the metallic grinder.

Very nearly all my polishing is done on the machine I shall presently describe; but before doing so, I will, with your permission, say a few words on the general principles of the polishing process. Various substances are used for the face of the polisher—fine cloth, satin, or paper, and pitch. Pitch possesses two important qualities which render it peculiarly suitable for this work, and it is a curious fact that we owe its application for this purpose to the extraordinary perspicuity of Sir Isaac Newton, who we may fairly say was the first to produce an optically perfect surface, and that that material is not only still used for the purpose, but is, as far as I know, the only substance which possesses the peculiar qualifications necessary to fulfill the required conditions.

With skill and care, moderately good surfaces can be obtained from cloth polishers; but it is easy to see why they can never be perfect. There is a certain amount of elasticity in cloth and in its "nap," and there is consequently a tendency to round off the surfaces of the pits left by the grinding powder, and to polish the bottom or floor of these pits at the same time as the upper surface. It is easy to show mathematically that any process which abrades the floors of the pits at the same time as general surfaces even in a very much less degree, can never produce more than an approximation to a perfect surface, and practice agrees with the theory. Paper is said to be much used by the French opticians. I can say nothing about it. I have tried it and failed to produce a perfect surface with it, nor indeed should I expect it. It is of course open to the same objection as cloth. Pitch possesses, as I said, two most important qualities which render it suitable for the work; the first, in its almost perfect inelasticity; the second, a curious quality of subsidence, which we utilize in the process.

If we watch with a microscope, or even a magnifier, the character of two surfaces during the process of polishing, the one with cloth, and the other with pitch, the difference is very striking. With the cloth polisher, the polish appears much quicker, and it would at first sight appear as if the same polishing powder abraded more quickly on the cloth than on the pitch polisher, but I do not believe that such is the case, for if we look at the surface with a magnifier we shall find that, while all the surface has assumed a polished appearance, the surface itself has retained some of the form of the original pitted character with the edges rounded off; while in the pitch half-polished surfaces the floors of the pits are as gray as ever, and the edges are sharp and decisive.

In pitch polishing, too, a decided amount of polish appears very quickly, and then for many hours there appears to be little or no further effect. Suddenly, however, the remaining grayness disappears, and the surface is polished. The reason of this is very obvious. The polisher being very inelastic polishes first only the tops of the hills, and has to abrade away all the material of which these hills are composed before it reaches the valleys or floors of the pits. When it does reach them, the proper polish quickly appears. The second quality of pitch, that of subsidence, is also most valuable.

Pitch can be rendered very hard by continued boiling. By pitch I mean the natural bituminous deposit which comes to us from Archangel, not gas-tar pitch. It can be made so hard that it is impossible to make any impression on it with the finger-nail without splitting it into pieces; and yet even in this hard condition, if laid on an uneven surface, it will in a few days, weeks, or months subside and take the form of whatever it is resting upon. The cohesion of its particles is not sufficient to enable it to retain its form under the action of gravity; and as this condition is that which science tells us marks the difference between solids and liquids, we must, paradoxical though it may appear, class even the hardest pitch among liquid instead of solid substances.

Now, how do we utilize this peculiar quality?

The polishing tool is made by overlaying a metal or wooden disk formed to nearly the required curves by a set of squares of pitch, and while these are still warm pressing them against the glass, the form of which they immediately take.

In the grinding process I showed you that the regulation of the abrasion was managed partly by the character of the stroke given, and partly by the local touches given to the tool by the stoning process.

In polishing we still retain the same facilities for modifying the stroke, and the same rules I gave apply generally to the polishing process as well as the grinding; but we have not got any process equivalent to that of the local stoning, and even if we had it would be useless, for this very quality of subsidence of the pitch would in a few minutes cause any part of its surface which had been reduced to come into good contact again; we must therefore look for some other means for producing more or less abrasion whenever we require it. This we effect by modifying the size of the squares of pitch in the various zones. Practically, it is done in this way by a knife and mallet. Whenever the squares are reduced, the abrasion will be less.

This is a well-known method of regulation; but the *rationale* is, I think, not generally understood. It is generally explained that there is less abrasion because there is less abrading surface. I do not think this is the true, or at least the entire, explanation. In order to understand the action, you must conceive the pitch to be constantly in a state of subsidence, the amount of that subsidence depending of course on the pressure placed upon it. Now, if we reduce the size of the squares in any zone while retaining the same distance from center to center of squares, we increase at first the pressure per unit of area on the pitch squares in that zone, and consequently the subsidence will be greater, and the action will not be so tight or severe on that zone.

I know of no substances but pitch and a few of the resins which possess this peculiar quality except perhaps ice, and it is curious to think that the same quality which in ice allows of that gradual creeping and subsidence and consequent formation of glaciers, with their characteristic moraines, etc., will in pitch help us to produce accurate optical surfaces.

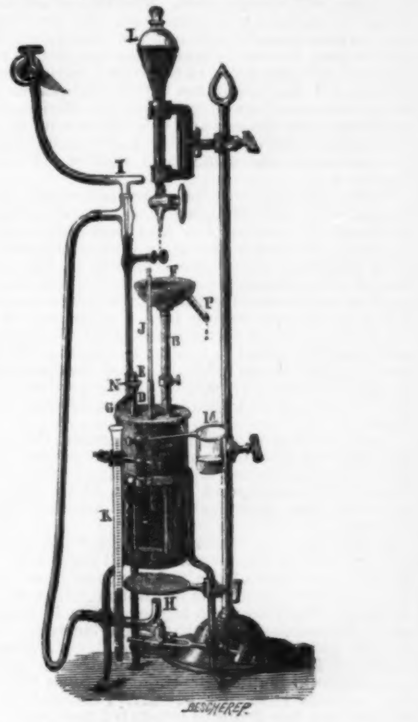
(*To be continued.*)

BARBEY'S IXOMETER.

THE apparatus illustrated herewith is styled an "ixometer," and is designed for measuring the degree of fluidity of oils. It has been the object of its inventor, Mr. Barbey, in arranging it to obtain a constancy in temperature, as this has a great influence upon the degree of viscosity of fatty bodies. From this point of view, the majority of viscometers that have been devised leave much to be desired.

The apparatus comprises a water-bath, A, for heating the oil to the temperature marked by a thermometer, J, through the intermedium of a gas burner, H, provided with a temperature regulator, I. Into this bath dips a V-shaped tube formed of the three parts, BC, OC, and OD. The first of these carries a funnel, F, which is fed by the oil reservoir, L. The second branch, OD, which is slender, is traversed by a steel rod whose extremities appear at E and O, and which performs a role analogous to that of the moderator of the Franchot lamp, leaving but a narrow and accurately determined passage for the flow of the oil. Such are the essential parts of the apparatus.

In order to make use of it, the cover is removed, the water-bath is filled, the rod is removed, and the whole affair is placed upon the small boiler. The reservoir, L, having been filled with the oil to be tested, and placed over the funnel, F, the liquid is allowed to flow until it begins to run out of the waste-tube, G. The upper cock having been closed, the rod is put back into its tube and the bath is heated to the temperature desired for the experiment through the intermedium of the heat regulator, I. When this point has been reached, and has remained invariable for a few minutes, oil is again allowed to flow from the reservoir drop by drop. After ten minutes, if the thermometer is still marking the same degree, the measuring is proceeded with. To effect this, the graduated tube, K, is placed under the waste tube, G, and the precise moment is noted at which the first drop of oil falls. When the flow has been prolonged for exactly ten minutes, the test tube, K, is immersed in the bath and kept there until it becomes of the same temperature, when the number of divisions occupied by the oil is read upon the graduation, and this will be the degree of fluidity sought at the temperature that has been chosen.



BARBEY'S IXOMETER.

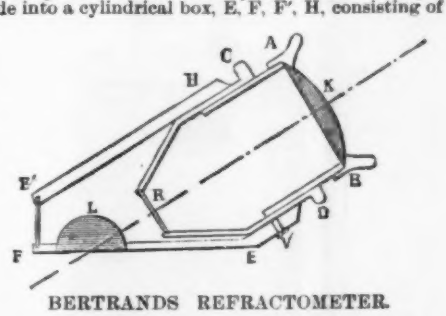
Thus we find that the fluidity of various oils at 35° is given by the following coefficients:

American petroleum	51
Russian "	43
Colza oil	84
Olive "	105
Peanut "	104
Fish "	135
Oleic acid	138
Castor oil	13

Mr. Barbey's apparatus permits of operating at all temperatures between 0° and 100°, but that of 35° has been adopted as being the one oftenest developed in the chambers of steam engines.—*Chronique Industrielle.*

BERTRAND'S REFRACTOMETER.

THE quick analysis of solids and liquids is a subject that deeply interests not only the physicist, chemist, and mineralogist, but also all those who have to find out almost instantaneously the nature of a material for an industrial or commercial valuation. The distinguishing of precious stones from each other, especially, is a delicate operation, and one that requires to be done quickly, although an error may lead to grave consequences. Mr. E. Bertrand has recently devised a small apparatus which he calls a refractometer, and which answers these difficult requirements. The apparatus is but two inches in length by one inch in diameter, and comprises an eye piece, a reticule tube, and a cylindrical box. The eye piece, AB, consists of a copper tube, to the upper part of which is screwed a collar that holds a crown glass lens ⅜ of an inch in diameter and of 1½ in. focus. This eye piece slides with slight friction into the reticule tube, CDR, which at its lower end is conical, and carries a reticule, R. This latter consists of a glass disk ¼ in. in diameter, provided in the center with 80 divisions $\frac{1}{10}$ of a millimeter apart, and numbered by tens. These two parts slide into a cylindrical box, E, F, F', H, consisting of a



BERTRANDS REFRACTOMETER.

tube cut at one extremity according to a plane that makes an angle of 30 degrees with the axis. Upon this elliptical section there is fixed by screws a copper disk which carries a hemispherical lens, L, of flint glass, and of ⅕ in. radius. The plane surface of this lens corresponds to the external surface of the disk, and its center is in the axis of the apparatus.

An aperture, FF', closed by a piece of ground glass, permits light to enter at the end opposite the eye piece. At V there is a screw that serves to hold the reticule tube in place, after it has been regulated, so as to keep the reticule in the focus of the lens, L.

So much for the apparatus; now let us see how it gives the index of refraction of a substance. Let us suppose that we have put a drop of liquid upon the plane face of the lens. Then, the luminous rays, entering the lens, will undergo a refraction due to their passage from the air into the glass, and will reach the surface of the liquid. Of these incident rays, some will

enter the liquid, and others (those which make an angle greater than the extreme one, F, with the perpendicular to the point of incidence) will undergo a total reflection and light up the lower portion of the reticule, while the upper portion, which receives no luminous ray, will remain dark. The line of separation of these two regions will vary with the limiting angle, and, as this latter depends upon the index of refraction, it may be readily seen that the position of this line will give the index of the liquid submitted to experiment if the apparatus is properly graduated. We shall, then, read upon the scale the division through which this line passes, and this latter will be so much the lower in proportion as the index, n, is greater, since F increases at the same time with n. So much for liquids.

With solids the principle is the same, and the operation is as follows: We place a plane and polished part of the object against the lens and interpose a little liquid of an index higher than that of the solid, since a total reflection cannot occur on the surface of separation of two substances unless the luminous rays are passing from one refracting medium into another that is less so. Upon looking into the apparatus, we shall see two lines—one corresponding to the index of the solid, and the other to that of the liquid. It is the former of these whose position must be read upon the graduated scale. It would be impossible to confuse the two, since the liqud used is determined in advance.

In order to graduate the apparatus, the indices of the different liquid or solid substances are accurately determined, and then it is ascertained what divisions of the reticule correspond thereto. After this a table is prepared that gives the index corresponding to each division.

In giving the method employed with solids, we remarked that the immersion liquid must have an index greater than that of the substance to be studied. For bodies of low index, such as fluorine, oil or benzine may be used. For those of a higher index, it is well to employ dibromated naphthylphenylacetone. This substance, which was discovered by Mr. L. Roux, has an index of 1·7, and may consequently be used for almost all solid bodies, for there are but a few whose index exceeds that of this. Mr. Bertrand in using it adds to it a few drops of bromated naphthalene, which lowers its index but slightly and renders it completely liquid.

In order to fully appreciate the real value of this new instrument, and to understand its advantages and simplicity, it will suffice to recall the "Newton method" that is generally employed for measuring indices. Here, if it is a solid body, we give the specimen the form of a prism, and measure the angle, A, of the latter, and obtain the value, D, of the minimum deviation. After this we calculate the index, n, by means of the formula

$$n = \frac{\sin \frac{D+H}{2}}{\sin \frac{A}{2}}$$

These operations necessitate the use of complicated instruments, certain notions of mathematics and physics, and lengthy calculation. With liquids the difficulty is still greater; moreover, this method cannot be applied unless we have on hand a sufficient quantity of the substance to use at our will.

The refractometer, on the contrary, furnishes the index upon a simple reading, and without the necessity of breaking or destroying the object. It gives the two first decimals accurately, and even the third with in about two or three units—this being a sufficient approximation in many cases. It can be used with advantage by jewelers and lapidaries, since it permits of distinguishing genuine from imitation stones, owing to the difference in their indices.—*Le Genie Civil.*

APPARATUS FOR DISTRIBUTING SULPHIDE OF CARBON.

WHEN sulphide of carbon for destroying the phylloxera is not distributed by a plan devised for the pur-

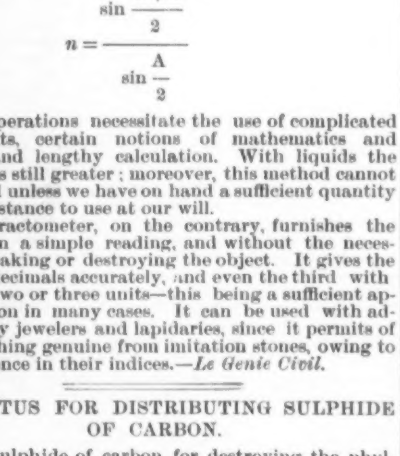


FIG. 1.

pose, it is poured or injected into the ground by various devices that permit of a given quantity at a time being dosed out.

The best known injecting apparatus consists of a can of a size such as to render it portable, and in the center of which there is a pump, which, at every piston stroke, sucks up some of the liquid and injects it into a hole made for the purpose. In most cases the force pipe is strengthened, and tapers to a point, so as to serve as a sort of dibble for making a hole in the ground. In all these apparatus the pump is not visible, and it is not

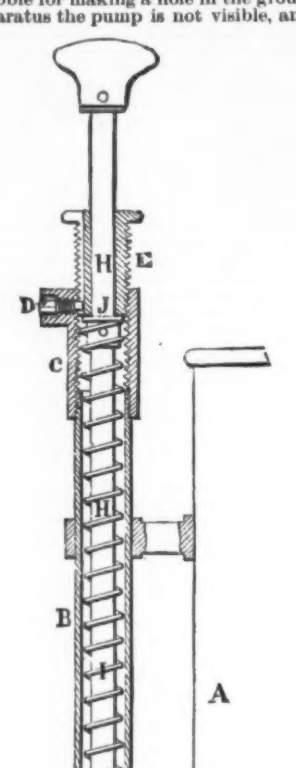


FIG. 2.

easy to inspect the internal parts. Moreover, an exact portioning out of the liquid is not secured.

Mr. A. Lafare, of St. Marcel, France, has devised quite a simple apparatus, which is herewith figured in perspective in Fig. 1 and in section in Fig. 2. The tools for forming the holes are shown in Figs. 3 and 4.

The cylinder, B (Fig. 2), in which the piston rod moves, is provided below with a flange which is connected by bolts, T, with the piece, L, that contains the suction valve, o, and the force valve, h. The pump chamber, K, is inclosed between the two pieces, B and L, and is made of glass, so that the liquid and piston may be seen. The graduation that it carries shows the

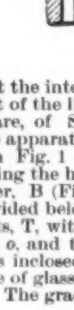


Fig. 3.

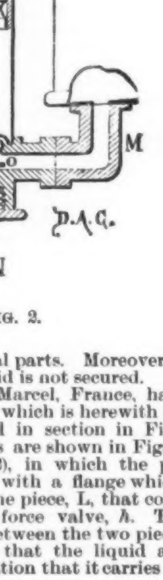


Fig. 4.

quantity of sulphide injected, according to the different positions of the piston, P. The latter consists of two disks of hot-pressed leather, and is held at the upper end of its travel by a spring, I, which rests below upon the bottom of the cylinder, B, and which above bears against the flange of a socket, J, keyed to the rod, H. The height to which the piston rises, as well as the quantity of liquid sucked up and ejected, is varied by means of an arrangement fixed to the upper part of the cylinder, B. Upon the threaded piece, C, screwed on to the top of the cylinder, B, there is screwed a long nut, E, traversed by a groove, with which engages the end of the screw, D, that serves to fix the nut. According as this latter is screwed up or unscrewed one or two turns, the position of the piston will vary, by one or two divisions, each thread of the nut, E, corresponding to one graduation of the cylinder, K. The head of the screw, L, is square, and is countersunk. It can be moved only by a key like that of a clock, and so, if the workman is not in possession of this key, he cannot vary the amount of liquid injected.

The piston rod carries a button which is acted upon by the palm of the hand, while the fingers bear against two small projections on the piece, C (Fig. 1).

The measured liquid is injected through the tube, N, to which is adapted the nozzle, F (Fig. 3), which is inserted into the hole in the ground made with the tool, G (Fig. 4). This apparatus has certain advantages over all other known systems, all the parts being visible and accessible, and easy to verify and repair. Moreover, the measuring is very accurate, the piston, P, always reaching the bottom of the cylinder and forcing out every bit of the sulphide sucked in, and, in rising, stopping at various heights, according to the position of the nut, E, thus varying the quantity of liquid injected. This mode of injection is simpler than that in which a sulphureting plow is used, but is neither so expeditious nor so effective, a large part of the sulphide being injected to too great a depth to act. —*Chronique Industrielle.*

GAS ENGINEERING AND MODERN SCIENCE.*

By DENNY LANE.

IT is by some people imagined that our branch of engineering is not so scientific as those practiced by our friends the mechanical, or our generous hosts the civil engineers. I propose to show how all branches of physical science are connected—most of them very intimately connected—with our industry. In doing so, I propose to take a broad view of modern science—to show how all its departments are so closely linked together that they practically become one.

All our knowledge of material nature is communicated to us by the senses. These stand as janitors at the portals ready to receive every message sent to us within from the world without. In most cases—perhaps in all—these messengers, who bring us tidings of weal or woe, have no independent existence; they are but the waves of that imponderable ether that fills all space, or of the crasser air in which our bodies are bathed, or the vibrations of the denser liquids and solids that we can more easily feel and weigh and handle. The aggregates of these vibrations we call the forces of nature; and by them all her wonderful actions and interactions are regulated. Swift messengers they are, most of them leaving "the herald Mercury" far behind in the race—from the wave of sound that travels over less than a quarter of a mile in a second to the ray of light that covers 186,000 miles in the same time. But more wonderful than the speed is the deftness of their flight. A large multitude of men, to be counted by thousands, are assembled by night looking up at a hemisphere powdered over with stars to be counted by myriads; yet each "bright particular star" sends its skein of rays to each and every eye in that vast multitude—skeins that never ravel, never tangle—speeding in every possible direction without haste, without rest. With inconceivable swiftness, there is yet no hurry; with inconceivable number, there is no confusion. Not one of the swift messengers jolts his neighbor from his path. Or look at garden and woodland. Not only every petal and every leaflet, but every microscopic point of each sends forth its troop of heralds, each wearing a tabard of its own color; each, without obstructing his fellows, fleeing to deliver his embassy to the brain. Or take an orchestra. Each instrument utters some one or more notes; but each note, again, is made up of many sounds—the ground tones and the overtones—the partials few or many. From each instrument each sound speeds to each ear in a vast audience. They also cross and recross each other, but never jostle. Again no hurry, no confusion. In opener or more serried ranks, swiftly, but with measured paces, they speed to bring each its message to the mind of man.

Wonders are these, that grow more wonderful the more we ponder over them, in the infinite variety, power, and beauty of each. But how must our admiration increase when we come to think that all these mighty powers are one; that each can exist only as the product or the cause of some other; that each may be converted into another, but then ceases to exist in its previous form; that all this apparent complexity is founded upon absolute simplicity—upon a complete oneness; that the power which marries the unsubstantial elements, and unites them into the drop of water; that the power which compels gold to become as fluid as water, or dissipates the solid rock into thinnest air; that the power which, in a moment, sends our words across an ocean so broad that "the lightning's wing sinks half way o'er it like a wearied bird;" that the power which, from trumpet, or from timbrel or psaltery, can arouse or allay our passions; that the power that opens our eyes to feast on the beauty of art and nature, and enables us to look into the face of our fellow-man—that all these great and beneficent powers are really one; that they are all translations into different tongues of the one great central organic law which governs the universe. This law is that the sum of all the forces is a constant quantity—that, therefore, energy can neither be created nor destroyed. It may assume different forms, just as a ponderable body may exist in the solid, the liquid, or the gaseous form. As with the latter we can neither add nor take away a grain of its weight, so with the former we can neither increase nor diminish by a single unit one of those microscopic waves which sometimes scarcely exceed in length the hundred-thousandth part of an inch, and in duration do not reach the millionth part of the millionth of a second.

I fancy I hear some one murmur, "Wonderful, truly! But what has this to do with us or our affairs?" I an-

* From the Inaugural Address before the Gas Institute, June 8, 1886.

swer, "Everything." It is with these forces of nature we have to deal; and I propose to show how essential a knowledge of them is for an educated engineer. I feel that I cannot have diminished the interest of the necessary study by showing how such learning is allied with the grandest contemplations of philosophy, the broadest generalizations, or the admiration of nature in all her sublime beauty. Let us see what these agencies are—light, heat, mechanical power, sound, electricity, chemical affinity. The very names of most of them at once tell how closely they are tied up with your daily work.

To the younger members of our Institute who desire to study physical science, I would venture to suggest that they should commence with some knowledge of the correlation of the physical forces. On this subject the work of Justice Grove, who first broadly laid down the principle, is, of course, a classic; but a sufficient elementary knowledge can be gleaned from simpler works, such as that of Dr. Balfour Stewart. This first principle of correlation is, to my mind, the soundest basis on which to build a solid scientific education.

I will first touch upon that branch of science with which we have the least concern—acoustics. Although not directly of much importance to the gas engineer, the study of the science forms the easiest introduction to the wave theory; and this undulatory theory pervades, to a greater or less extent, every branch of science. The science of sound may yet have practical applications for us. The pitch of all musical instruments changes with the temperature; and hence it is not unlikely that we may have an acoustic thermometer—mayhap an acoustic photometer—which will translate waves of light into waves of sound. You have, I suppose, all seen or heard of the singing flames, in which the converse takes place, and the waves of sound are made visible. We have one musical instrument played on by gas-flames—the gas harmonicon—which in two respects so closely resembles certain human voices, namely, in the facility with which it gets, and the persistency with which it remains, out of tune. In the telephone, which so many of you employ, you have the case of a double conversion, first of sound, which, having been changed into electricity, passes as such along the connecting wire, and at the other terminal is reconverted into sound—a relapse of which we have not a few instances in the history of religion. Again, the ingenious Mr. Edison has invented what he terms a sound mill, a contrivance by which the vibrations of the human voice are utilized as a mechanical power—an engine which I trust may yet take an important place in practical mechanics, by turning to some purpose the now useless garrulity of politicians and other old women of both sexes.

I will now refer to the agency which has been the longest known of any, and which, within certain limits, was thoroughly understood by the ancient Greeks, and even earlier races—I mean mechanical energy. So far as the action of solids on each other is concerned, their works leave evidence that they must have employed mechanical engines which produced results that would tax the ingenuity of the engineers of to-day. The builders of the Pyramids, unprovided, as they were, with the aid of steam, must have employed some dynamic contrivances of which we have lost all trace; and it is still a perplexing problem to the most inventive minds how these immense masses were raised to such great heights. The raising of a given weight to a given height is one of the compound units of all mechanical science; and when combined with the unit of time, may be said to embrace all mechanical problems. The mechanics of fluid bodies—hydrostatics and hydraulics—were also thoroughly studied long ages ago. The aqueducts of the Romans, eighteen of which led to the Imperial City alone, are evidence of the knowledge of this practical people. The mode of determining specific gravity was invented when, two centuries before our era, the philosopher determined with how much baser metal the golden crown of Hiero was alloyed. The "Hydraulics" of Hero of Alexandria, which was written in the next century, contains a number of most ingenious contrivances which have been copied or reinvented over and over again down to our own day. While on this subject, I would wish to restore to its rightful owner that most ingenious hydrostatic contrivance, the compensator, employed in the "Unvarying Water-Line Meter." I have found it accurately described in a book called "Lampas," published by the celebrated Dr. Robert Hooke in 1677; and it was invented for the purpose of keeping at a constant level the oil in the old single-wick lamp. Mr. Donovan, a clever mechanic of Dublin, first applied the system to steam-boilers; and, in conjunction with the late Mr. G. Saunders, patented its application to gas-meters. It is possible, but very unlikely, that it was reinvented, instead of being copied, by Mr. Donovan. Mr. Saunders was very much surprised when, some years ago, I showed him, in the Dublin University Library, in a book of so old a date, exactly the same contrivance as that which he thought was of recent invention—a contrivance which, for a beautiful application of the laws of gravity, has, I think, never been excelled. It is a curious coincidence that the compensator, first invented to regulate the light from oil, should now be applied to so cognate a purpose, although the circumstances are so much altered. With hydraulics or hydrostatics, however, our profession has little to do.

In the third branch—the mechanics of gaseous bodies—you are deeply concerned. In this the ancients had not made much progress; and the foundations of the modern science were really firmly laid by a neighbor of mine (one born in my own province), the Hon. Robert Boyle, whose relations with science and the peerage were put in so succinct a form by one who described him as the "Father of Modern Chemistry and Brother to the Earl of Corke." But although so described, his chemical offspring are forgotten; while in pneumatics he laid down the laws which every one of us knows regulate the pressure, volume, and flow of all gases. Your mains subserve the same purpose as a railway; they form a link between the producer and consumer. Where water and gas mains do not exist, not only the contents, but the containing vessel, had to be carried from place to place. Such was the case, too, in the early days of gas lighting, where portable gas was carried, like coals, to the cellar—a system I saw in operation in Paris not long since; and this, in a modified form, is still used for the carriage of oxygen, carbonic acid, and "laughing gas." But iron mains and iron roads, which carry while they do not move, have enormously increased the commerce and convenience of the world. There is no branch of mechanics which is more intimately connected with your business than the science of pneumatics. Fortunately, the principles, so far as they concern you, are simple. But the experimental data are not so abundant as might be wished for; and I think it would be desirable that our leading engineers should make still further experiments on the flow of gaseous fluids in large mains. During the construction of new works, while the mains are not required for use, such experiments could easily be made with little expense; and we have among those I see around me engineers who, I hope, will take a note of this suggestion.

A most important pneumatic instrument is the governor. For the supply of large quantities of gas, either to mains or to consumers, the governor has attained great efficiency; but when it is applied to so small a volume as that required for the supply of a public lamp, my experience is that much improvement is needed. It is quite true that several such regulators will act well when they are new; but after some time they need constant repairs and regulation. I am sure that companies working by the average meter system lose much from these variations. The defect I mention is not to be wondered at when we consider the very small apertures which are necessary, and their liability to be clogged by particles of dust, of oxide, or of oil. It would be desirable that some member should take up this subject, and, by periodical tests, determine the extent and cause of such fluctuations, and thus stimulate the minds of inventors to overcome, if possible, these defects. As yet, the automatic regulation of variations of pressure has not been much employed, and where several mains have to be governed at different pressures, the apparatus becomes expensive. I made some attempts myself to effect this purpose more cheaply by an electric current. Although I was not successful, I am sure that such a system will eventually be carried out. The question is not of much importance. As foremen and engine men must be employed night and day on gas works, and as the pressures can be recorded by a register, automatic regulation is not so necessary as in other cases. Another matter that well deserves more extended experiment is the law regulating the flow of gas through very small apertures. While through large apertures the flow varies nearly as the square root of the pressure, some observations seem to show that through small orifices the variation approaches to the simple more nearly than to the subduplicate ratio of the pressure. This is a question very important in reference to leakage; and some of our members will, I hope, investigate it carefully. The necessary experiments require only time, attention, and good measuring instruments.

It is unnecessary for me to refer to such questions as the relation between the pressure and the weight of gasholders; but I may remark that large single lift holders are sometimes made too light to give a sufficient pressure. It would be better to put additional weight in the structure itself than to leave this to be afterward supplemented by weights, which it is not easy or convenient to apply. Any additional cost would be paid for in the increased durability of the holder.

I have but few words to say in reference to the last portion of our distributing plant—the meter—which, much as it is condemned by those who know nothing about it, is justly regarded by those who really understand it as one of the most simple, ingenious, and practical of modern inventions. It does not aim at scientific accuracy. With a body whose volume varies with every change of temperature and pressure, such a result can never be practically attained; but as an honest accountant, striking a just commercial balance between buyer and seller, it does its duty admirably. The variations that occur from absolute accuracy are more likely to be in favor of the buyer than of the seller; but they are of little moment—to be measured perhaps by a quarter of a penny per 1,000 cubic feet in price, or by a quarter of a candle in illuminating power. Even if the difference operated against the consumer, the loss would be compensated for tenfold by the illuminating power which most companies give in excess of their legal obligations. The gas meter involves little knowledge of physics, as it is rather a mechanical contrivance than a scientific instrument in the strict sense of the term; and its principles belong more to the new science, kinematics, than to pneumatics proper.

The exhauster is the only pneumatic engine which is peculiar to gas works. Its principles are extremely simple; but here again it may be observed that more data are needed. It would be desirable that the steam engine should be more frequently tested by the indicator, and the cards compared with the registration of the station meter and pressure gauge. Some careful experiments in this direction were made by Messrs. Bryan Donkin & Co.; but such experiments need to be multiplied and extended. Before leaving this subject, I may remark that it is strange that gas engines are so seldom used for exhausting purposes. The only difficulty that I see is in the fact that the best gas engines require to be driven at a nearly uniform velocity, while the exhauster must change its speed. But some automatic apparatus of the nature of cone pulleys or washer wheels may be introduced, which would overcome this difficulty. The great economy of a gas engine employed in gas works, and the little attention it requires, should recommend its use to the engineer.

I now come to the great agent of production in our industry—heat; and of this, although we are not as wasteful as the steam engineers, who waste from 90 to 98 per cent. of the whole heat produced, still I feel that we are improvident. Every one who knows what a large volume of heated gas escapes from the retort-bench must feel this, and the various forms of regenerators have been introduced with the purpose of saving some of the loss. As a general rule, these have been expensive; and, as far as I know, have been used only where gaseous fuel has been employed. My colleague, Mr. Travers, has been making some experiments with a view to saving the waste heat of coke fires. These are still in progress, are sound in theory, and promise practical success. The great future to be looked for is, however, when we can dispense with retorts, and when gas can be produced by some continuous system, as in a blast furnace. In the production of water gas this has already been half effected. The one structure is alternately used as a furnace and as a retort; and a valuable heating gas has been produced. A system, either continuous or alternate, applicable for illuminating gas, seems to be a problem not too difficult for solution. The great wear and tear and the interruptions incident to the present system are very great; and perhaps the youngest of you may yet see the gas retort placed alongside the steam engine in that "cabinet of antiquities" which the prophetic eye of Sir Frederick Bramwell has so clearly foreseen, and in which, I venture to add, he has not "imagined a vain thing."

Besides the illuminating gases produced from coals, cannels, and oils, three heating gases are now employed, each incapable by itself of producing any useful light. The first—"producer" gas, arising from the chemical reactions of air, steam, and carbon at high temperatures, although evolved from blast and generator furnaces in immense quantities—labors under the disadvantage of being very bulky; being diluted with the inert nitrogen of the air, which supplies also the oxygen required to form the oxides of carbon contained in this gas. Its great bulk (about five times that of ordinary gas) leads to so much difficulty in distribution, that producer gas is never used at any distance from the place where it is generated. Water gas, not being diluted with nitrogen, and consisting mainly of hydrogen and carbon monoxide, is not so bulky.

Quite lately, French chemists—MM. Felix Hembert and Henry—have communicated to the French Academy an economical mode of producing hydrogen. Over hot coke in a retort, steam is passed; the products (being hydrogen monoxide and dioxide of carbon) are conducted into a second red hot retort charged with fragments of some refractory material. Into this an additional dose of steam passes; its hydrogen is liberated, and its oxygen combining with the monoxide converts it into the dioxide of carbon. All the latter gas is then taken up by lime, and tolerably pure hydrogen passes over. It is alleged that 1 ton of coke can produce 112,000 cubic feet of hydrogen, at a cost of 4d. per 1,000 cubic feet. Perhaps this may be the sanguine estimate of the inventors. Of all bodies, hydrogen, weight for weight, yields by its combustion the greatest quantity of heat—62,000 English units per pound, or about five times as much as coal, or three times as much as lighting gas.

On the other hand, its specific gravity is so low that its volume is about six times that of gas. Hence about 1,000 cubic feet of coal gas are as good as 2,000 cubic feet of hydrogen for heating purposes; and, on account of its excessive tenuity, the leakage of the latter must be very great. Hence I think it will not become a dangerous competitor of illuminating gas, which has, volume for volume, a thermal efficiency so much higher.

In the distillation of coal or the condensation of gas, we cannot boast of much progress. Looking back for many decades of years, the introduction of clay retorts and of the exhauster forms the only indubitable harvest of half a century. Gaseous fuel and regeneration are, I may state, still on their trial; and there is no universal concurrence as to their merits. Besides retorts, the boilers also require fuel; and here we are somewhat differently placed from other steam users.

We have also a large quantity of breeze and small coke which is of little or no value away from the works. Perret's furnace for using breeze has lately been introduced into this country. The principal difficulty in burning breeze has arisen from the fact that its small particles fit so closely together that the draught is obstructed. In the new furnace the difficulty is overcome by an induced current of air introduced with steam beneath the furnace bars, which are kept cool by feathers projecting from their lower surfaces, and dipping into water.

The carbon monoxide produced and hydrogen liberated cause a flame which transfers a portion of the combustion and heat into the flues; thus preventing excessive temperature in the furnace proper. With respect to heat, we have abundance of teachers. Tyndall's lectures are most attractive; while Clerk Maxwell's treatise, although admirable as a work of science, could be made much more interesting if it dealt more with practice and experiment. It is a work not very easy nor withal very difficult for an attentive student. A multitude of authors have written well and clearly on the production and applications of heat.

The next point to which I will call your attention is the conversion of heat into power. For many years attempts have been made to work steam-engines by gas-heated boilers; but illuminating gas was found to be far too expensive a fuel. Producer gas has lately been employed for this purpose; and it enables us to use very inferior coal. Indeed, by this system steel can be melted by small coal containing 30 per cent. of ash. It was not, therefore, until the introduction of the gas engine that illuminating gas was economically employed for the production of power. At our last meeting I went so fully into this subject that there is little for me now to add.

The year has been productive of abundant litigation, not only in this country, but in France and Germany. Here the Otto patent for the fourfold cycle has been maintained; while abroad we are led to understand that the previous publication of the system by Beau de Rochas was held to invalidate the Otto claims. The decision in this country turned upon a curious technical point, for it was decided that the existence of a book in one room of the British Museum Library was not a publication, while if the same book had been accessible in another room the patent of Otto would have been invalidated.

A great amount of ingenuity has been exercised on the designs for the gas engine; and I may especially refer to Atkinson's differential engine, of which I showed you a small sectional model last year at Manchester. The motion of the double piston, producing in one revolution of the crank shaft four changes of volume in the cylinder, is very ingenious, and in a practical way dispenses with the necessity for a slide valve. I have just seen a report of some experiments, which appear to have been very carefully made, with one of these engines developing between from 2 to 3 horse power, and which show a consumption of only 26 cubic feet per brake horse power—an economy most satisfactory in so small a motor. Korting's, Simon's, Tangye's, Andrews', and some other engines are all well worth the study of those interested in the subject. The size of these motors has also been increased; and Messrs.

Crossley have now in operation one engine giving with a single vertical cylinder 120 indicated horse power. This has a cylinder 19 inches in diameter with a 22 inch stroke, and makes 160 revolutions per minute. It is calculated that this motor will require only 15 cubic feet per indicated horse power per hour. Where the price of gas is at its lowest, 1 horse power would, on these data, cost only one-third of a penny per hour.

Mr. Crossley has lately invented a new governor on the cataract principle, which insures a much more regular speed—a matter of considerable importance where gas power is employed to produce the electric light; for every variation in velocity causes a variation in light. The regulation is effected not by cutting off altogether, for one or more strokes, the supply of gas, as is done by the ordinary governor. The new regulator, operating on three cams instead of one, gives a stronger or weaker charge at every cycle, but never permits the piston to perform an idle stroke. This contrivance is now applied to a 9 horse power engine to supply electric light at the Alhambra Theater. I may add that an ingenious application of the explosive power of gas has been made in the gas hammer of Messrs. Tangyes—an application which I feel confident will, from its convenience and readiness of action, be largely developed. Since our last meeting I have learned that tramway cars have been successfully worked at Melbourne on a line with difficult gradients; thus dispensing with the smoke, noise, boilers, and furnaces, which have given so much trouble where steam has been employed. In this direction I look for further progress in gas engines. I expect that they will be made much larger, and also much smaller and cheaper, to act as domestic motors; and now that we know where the loss of heat takes place, I believe we are in the right way to remedy it, and so make this engine still more economical But even as it stands this motor holds the first place as a transmuter of heat into power; giving, as I explained to you last year, an efficiency more than double that of the best steam-engines.

The other applications of gas—viz., for heating and cooking purposes—are too numerous to refer to. For a long time I was opposed to the use of gas stoves for heating ordinary dwelling houses, as I did not think them either agreeable or wholesome; but of late the improvements made, especially in radiating stoves, have removed these objections.

The next of the great agencies of nature to which I will refer is that which most nearly concerns us—light. The thorough scientific study of this subject, including interference and polarization, requires a knowledge of the higher mathematics which few engineers possess; but the portion which most interests us is easy of comprehension. We have not to deal with the marvelous swiftness of light, or with those lapses of time which, notwithstanding such a velocity, are necessary to bring it to us from even the nearest of the fixed stars. We have little to do with refraction; and the testing power of the spectroscope, although applied to the manufacture of steel, has not yet reached our industry.

It is not impossible, however, that in photometry it may yet have its use.

We have principally to deal with three points—the production, the measurement, and the distribution of light. With respect to the first, it seems pretty well, though not absolutely, settled that, for all practical purposes, light must be derived from solid bodies maintained at a very high temperature. The oxyhydrogen blowpipe, with its intensely hot but scarcely visible flame, shows that heat alone is not sufficient to produce light; but the moment this heat is communicated to any solid body, such as a lime cylinder, a brilliant light is evolved. If the solid body be incombustible, as in the case of lime or platinum, this appears to be a simple conversion of heat into light. But if the solid be combustible, like the particles of finely divided carbon released in all ordinary lamp flames, a new quantity of heat is generated; but when the body has taken up its full equivalent of oxygen, the combination again becomes gaseous, and ceases to be practically luminous. The light of every flame depends, therefore, on two factors, viz., the number of particles of solid carbon it contains, and its temperature. With regard to the latter, we have seen this factor largely increased of late by the application of the regenerative system to lamps—an idea first imperfectly carried out in the double glass chimney of Dr. Normandy. The merit of this system, whether applied to furnaces or lamps, no doubt belongs to the two brothers, both of whom have contributed important papers to our transactions—I mean Sir William and Mr. F. Siemens. But their followers—notably Mr. Bower, Mr. Wenham, Mr. Sugg, Herr Schulke, and others—have greatly increased the efficiency of gas lighting by their inventions; and the last decade has done more for the luminous efficiency of gas than the previous half century. Although the experiment has never been practically made, I believe it would in some cases be economical to raise, from some external source of heat, the temperature of both gas and air before they meet and combine; and for lighthouse and similar purposes I am of opinion that such a plan will yet be tried. The other way in which we can increase the power of a flame is by multiplying the number of solid particles made luminous; and here, theoretically speaking, there is a wide field for research. The whole quantity of carbon in ordinary gas coal is about 82 per cent. Of this we get in gas about 16 per cent., or one-fifth of the whole; the remaining 66 per cent. remaining in the tar and coke. A portion, after having been made gaseous, is again condensed into a semi-liquid body in the tar. Some of the products of coal tar—from the light fluid benzol to the solid naphthalene—have been employed in order to restore to gas a portion of the illuminating constituents which were precipitated owing to their having fallen into the bad company of some of the worst products of tar. It would have been better, however, if their light-giving power could have been retained in the gaseous form. Both common resin and oil of turpentine have also been employed to enrich gas; but good cannel is the cheapest material yet introduced for this purpose. Although I cannot indicate in what direction the effort may be made, it seems probable that some larger proportion of the carbon may, by chemical or thermal agencies, be made volatile, as is done with water and furnace gases. With respect to the hydrocarbons remaining in the tar, some improvement has been effected. Different systems of enriching gas from this source are in operation; and to one of these your attention will be called during the present meeting. But besides carbon, other solid bodies, many of them more or less incombustible, are capable by their incandescence of yielding light; and the inventions of M. Clamond, Mr. Bower, and others have been intended to increase the power of our ordinary gas by the incandescence of solids, or by the same method to derive light from gases which by themselves are non-luminous. Considerable progress it is alleged has lately been made in this respect in Germany, where water gas is employed in large works for both heating and lighting. In such cases this mode may be useful, but for general purposes I believe it to be inapplicable, on account of the difficulty of finding any substance which, in a convenient form, can sustain the great changes of temperature to which such incandescent bodies are subjected. The idea is an old one; and in the earliest days of water gas, fine webs of platinum wire were tried, but were found to be very expensive, and not durable. I do not look for much improvement from this source.

The next question in reference to light is its measurement; and here the only material difficulty consists in the adoption of a standard. The sperm candle and the Carcel lamp still hold their places as commercial tests; but for manufacturing purposes I feel that the Methven standard is more convenient, uniform, and reliable. It has been our misfortune within the last year, by the death of Mr. F. W. Hartley, to lose a gentleman who had devoted much time and great ability to this subject; and he fully shared the opinion I have expressed. A standard lately proposed in France has every fault that a measuring unit could possess. It is expensive, troublesome, unreliable, and founded on a small number of experiments. The question is still *sub judice*; and it is not improbable that our friends the electricians may perform a kind office, and assist us to determine it. The refinement of their methods of measuring electric currents may serve to measure the light produced by glow lamps. I look with much hope in this direction.

You are all familiar with Joule's celebrated determination of the mechanical equivalent of heat—viz., 1 English heat unit=772 foot-pounds. Within the past year Herr Wilhelm Peukert, of Hanover, has for the first time determined the mechanical unit of light. Taking the candle as his unit, he has estimated its light as equivalent to 80 foot-pounds per minute. His method was simple. A glow lamp was submerged in a glass globe of water. The electric current passing through the lamp was measured in the usual manner, in *watts*, which are only multiples of foot-pounds. The quantity of heat communicated to the water was also estimated at its mechanical equivalent; and the difference was charged to the account of the luminous rays. Of every 100 units of current, about 70 were measured as heat from the Swan, Edison, and Siemens lamps; the remaining 30 units were debited to light, with a result showing about 80 foot-pounds per minute, equal to 1 candle. The light of an ordinary 5-foot burner with London gas would be equal to 1280 foot-pounds, or 1-25th of a horse power. A gas engine would give about six or seven times as much with the same consumption. With reliable volt-meters and ohm-meters, I am sure an electric standard of light will ere long be attained.

The automatic registration of illuminating power was tried some years at the Chartered Gas Works, but was found troublesome. Since that period, however, the introduction of dry plates has greatly simplified the operation; and I do not see why it should not be more successful now.

Another important matter well worth consideration is the proper distribution of light—a matter in which we enjoy great advantages over our friends who employ the electric arc. In fact, this is one of the advantages that enable us so well to hold our own. Taking simply units of light, we may admit that a system of powerful arc lighting on a large scale may be more economical than ordinary gas lighting. But, granting all this, it cannot be denied that by the latter we can have the light exactly where we want it, measured out, I may say, in retail quantities; while by the former we have a dangerous deluge in one place, which makes more remarkable an equally dangerous drought in another. The question of the best distribution of light is one that can be treated mathematically. The problem is how to secure in a given space a distribution of light nowhere falling below a given standard. For example, if in a circular space eight lights were used, it is clear that the illumination would be better if the lights were distributed along eight radii than if they were all collected at the center. I once paid some attention to this problem, but had not time to work it out; so I leave it to be solved by some of the younger mathematicians among our members.

I now come to that form of energy the knowledge of which has been so greatly developed within the present century, and which has received such numerous and important applications—I mean electricity. It is a very Ariel among the physical forces, and has performed more marvels than ever that sprite wrought at the bidding of the enchanter's wand. In a fraction of a second it becomes a mechanical power or a chemical agent. It flashes into light; and "ere a man hath power to cry, 'Behold!'" it melts into music, and "ere a man hath power to whisper, 'Listen!'" it flits away, a swift and silent herald to carry our messages "from China to Peru." It is the master and the slave of all the world's agencies—commanding and obeying, creating or being created. Hotter than fire, a hundred thousand times swifter than sound—nay, sometimes far swifter than light itself—with inconceivable speed it races round our globe, yet in its headlong course keeping the compass steadfast to the pole; now shedding a bland light from crystal flowers like the jeweled lamps of the Eastern story; now with unerring finger guiding by night and by day, in fog and in eclipse, the sailor across the pathless sea; and anon the messenger of death, striking with a lethal arrow, and leaving of proud man nothing but a blackened corpse. Potent, manifold, even among the ever-changing powers, it is the very Proteus of them all.

Among its many manifestations, it is not long since it shimmered before our eyes a ghastly specter threatening destruction to us and ours; and, like all other ghostly visitants, terrified most those who had not courage enough, or knowledge enough, to examine the apparition closely. I shall never forget the pallid faces of some of my friends. I tried to reassure them, but they would not be comforted; and it was with the greatest difficulty that I prevented some of them from fleeing in a groundless panic. I am glad to say I was to a great degree successful. But in other places the result was different; and it would be hard to calculate how immense were the losses incurred by the false depreciation of gas, and the equally false appreciation of electricity, as a light-giving power. Although I had formed my own conclusions on this subject very early, I hesitated to express them until I had consulted others with more experience than I possessed. The highest authorities on the subject (Sir W. Siemens being among the number) only corroborated and deepened the impressions I had formed; and we may say that up to this time the electricians have been our best friends. The fact was that some of us were sinking into an easy and unwholesome torpor, from which a powerful shock was necessary to arouse us.

It is neither good manners nor good sense to speak in a depreciatory way of a rival; and we may cheerfully admit that for the electric light there is space, and ample space, without evicting the elder brother from his freehold. In some factories—flour mills, for example—the glow lamps are undoubtedly safer than any other light. Where the expense and necessary attendance can be afforded, there can be no doubt that they yield a beautiful light, which, from its coolness, is especially agreeable in summer. Where, as is so common in Switzerland, water-power is abundant, the light is most economical; and for this reason I am about to light a starch factory of my own, beyond the reach of gas mains, with incandescent lights. In large railway stations arc lights can often be used with economy. Some (especially the "Soleil" light, from its purity of color) are admirably adapted for picture galleries; while for the lighting of large steamers, the glow lamps are all that can be wished for. In ordinary cases, however, the glow lamps are very expensive; and, while they may compete with gas sold at 10s. per 1,000 cubic feet, they are too dear for England.

So much for one of the principal applications of electricity; but it can be used in many small ways. I need not refer to telegraphs and telephones, now so generally used between offices and works; but I will call your attention to the facility with which governors at a distance can be worked by an electric current. At the Dublin Gas Works the stock of gas in a distant holder is automatically indicated in the engineer's office by a double electric current—one intimating the rise, and the other the fall, of the holder. Common electric bells form such simple alarms that they can be easily connected to steam vacuum and pressure gauges; and, I believe, can yet be made to indicate an undue fall in illuminating power. It is most useful in lighting gas flames placed either at a distance or in positions difficult of access. Several attempts have been made to employ an electric current for street lamps—thus dispensing with lamp-lighters; but the inventors (of whom I was one) have not attained any practical success. I am, however, confident that this object will yet be attained, and with economy, as it makes it possible to light or extinguish any group of lamps at any hour, and this without any electrical communication between them. To the ingenious engineer a hundred cases will suggest themselves in which this swift, potent, and flexible agent can be trained to do his bidding.

I have spoken of some of the applications of electricity. I have to say a few words on its production. For all small currents some form of constant battery is, of course, the most convenient; but occasionally a thermo-electric pile, heated by a Bunsen burner, may be used. This is another case of conversion—that of heat into electricity; and I wonder why it is not more frequently used. At a telegraph office in London I saw it employed for a local circuit which had been in operation day and night for many years without any care whatever; thus dispensing with the attention and renewals which all fluid cells require. This form would be peculiarly useful to us; but there seems to be some difficulty about procuring M. Clamond's thermo-electric batteries—the best I have seen. To show how small a quantity of heat may produce an electric effect, I may remark that Lord Rosse's experiments, by which he determined the very minute amount of heat radiated from the moon, were made by the aid of a current so obtained from our satellite. But for obtaining large quantities of electricity, the dynamo-electric machine stands alone. Indeed, as a translator of one form of force into another it is unparalleled. While the steam-engine converts into power only 10 per cent., and the gas-engine about 22 per cent. of heat, the dynamo-electric converts upward of 90 per cent. of power into electricity, and its antitype—the electro-dynamic—converts more than 90 per cent. of electricity into power. Indeed, recent careful experiments, made with the Edison-Hopkinson machine, show in exactly similar machines a mutual efficiency of 93 per cent. If, therefore, we expend 100 units of power, we recover 93 units of electricity; and if, again, we convert this electricity, we get back as power 93 per cent. of it, or 87 per cent. of the original quantity. Now, if we consider the necessary friction and heat produced in machines running at so high a velocity, it is wonderful how little is lost; and as to the future prospects of electric lighting, it is of the greatest importance, for we can positively assert that in the production of electricity from its cheapest source—mechanical power—no further improvement is possible. I have lately laid before the Corporation of Cork a proposal to employ this system to import into the city about 200 horse power generated by water-wheels situated about three miles away, by means of which there would be yearly saved upward of 1,500 tons of coal now used in the generation of steam, besides all the attendant labor and wear and tear of engines and boilers. Messrs. Mather & Platt, of Salford, are prepared to guarantee that a large percentage of the original power shall be delivered at this distance through a copper wire less than one-half inch in diameter. It is indeed in this direction, as an agent for transferring mechanical force to a distance, that electricity has a great field before it. I fear that in this application small gas-engines may meet with serious competition. A large gas-engine using only (say) 1·3 lb. of coal may be employed to drive generators at a central station; and if this delivered only 66 per cent. of its energy, the expenditure of coal would still be only equivalent to 2 lb. at the consumers' motors. As compared with hydraulic or pneumatic agencies or rope

traction, the electric system presents far greater economy in transmission.

Before I leave this subject I must point out one difficulty which applies to all physical forces—the difficulty of storage. The storage of mechanical power has never been practically effected except by water reservoirs on a very large scale. How large this scale must be, very few people take the trouble to reflect; but you may form some idea of it from a very simple formula of mine, with which I have astonished some engineers. It is this: Allowing to a turbine, or water-wheel, an efficiency of 75 per cent., it requires 1 acre of water 1 foot deep to supply even 1 horse power for an hour for each foot of fall. The water reservoir i the most practical method of storing any physical force yet tried; and still it is only in a few instances that it has led to satisfactory results. With respect to gas, few works have storage sufficient for more than one day's supply. The accumulators used in hydraulic engineering do not reserve one hour's work; and compressed air receivers have about the same capacity. Electricity can, to some extent, be stored in secondary batteries; but the waste is very heavy, the apparatus is expensive, and "its expectation of life" seems to be very limited. In fact, we have no means of putting into stock any form of force; and, practically, energy must be produced as it is wanted.

I have reserved till the last the force which by many will be deemed the first in importance—chemical affinity in relation to our pursuits. Perhaps the reason I have unconsciously done so is that the subject is, from its magnitude, so embarrassing. In every step in the manufacture of gas, chemistry is a guide. From the composition of the coal and the purifying agents (the raw materials we employ) to the products—solid, liquid, and gaseous—which are the results of our work, chemistry is everywhere the test by which we can determine whether this work is rightly done; and some of the most difficult branches of the science are those which most concern us. Chemistry is really a science of weight and volume. The gaseous bodies we have to deal with are very light, with every change of temperature and pressure varying in relative weight and volume. Hence, the chemistry of such bodies requires more delicate and more difficult manipulations than either solids or liquids, which are so much heavier and so much more stable in volume. Next, all the bodies with which we have to deal, except lime, oxide of iron, and sulphuric acid, are organic; and, therefore, their constitution is more complex, and their analysis more difficult, than those of inorganic bodies. And, finally, the theories and nomenclature of the chemistry of the carbon compounds is so complex and so frequently changing that it is hard for any one but a professional chemist to comprehend them.

If we look into the index of any book treating of the new chemistry, we shall see enough to satisfy ourselves of this difficulty. For example, a writer quotes the following passage from the *Journal of the Chemical Society*: "Some suppose pentanitrodimethylaniline was shown to be trenitromethylnitraniline; the substance in question has been obtained from napthyldimethamidophenylsulphone and diphenyldimethamidosulphone." I need not say that the analysis of such substances is far beyond the range of any man but one who devotes himself to the study of a science so complex. With all respect for the chemists, on the part of honest speaking people I must declare that the modern nomenclature of organic chemistry attempts too much, is unscientific, and would be barbarous only that it is unpronounceable. If men like Lavoisier, Dumas, and Liebig could have learned and taught as much as they did, in language not far removed from our ordinary speech, surely their successors need not have been driven to the use of a jargon more difficult than Volapuk, which has nothing of a language but the letters—a system which I suppose must have been invented, as it certainly has been developed, by our Teutonic neighbors, who, although a learned, are not a literary people, and whose own language has set them such a bad example of polysyllabic compounds. The chemistry of the products of coal tar is a science in itself. Aniline, anthracene, alizarine, carbolic acid, salicylic acid, indigol, I may mention as a few of the best known of its derivatives; but every day produces some new combination. Hitherto the most important among the bodies have been the disinfectants and the many dyes that are derived from the most volatile and the least volatile of the products of distillation. Within the last year we have heard for the first time of a new product—saccharine—which is said to have a sweetening power 230 times greater than that of sugar, and, strange to say, is not decomposed in the animal economy. It must therefore, while agreeable, be at the same time both harmless and void of all nutritive value. As yet, although its price is very high, and it is almost a chemical curiosity, it seems to be about as cheap as sugar as a sweetening agent; and it is said that its manufacture is about to be developed on such a scale that it will soon become far cheaper. The number of text books on chemistry is beyond count; but I would wish to direct the attention of both students and proficients to a small book by Dr. Josiah Cooke, of Harvard University, entitled "The New Chemistry"—a work which, founded on a few simple data, as a model of scientific exposition has never been surpassed. The same author's work on "Chemical Physics" was, when published, an unrivaled text book. It is, unfortunately, out of print; and, still more unfortunately, the author has not published an edition embracing later discoveries. Perhaps the extent of progress, especially in electrical science, has deterred a conscientious author from the task.

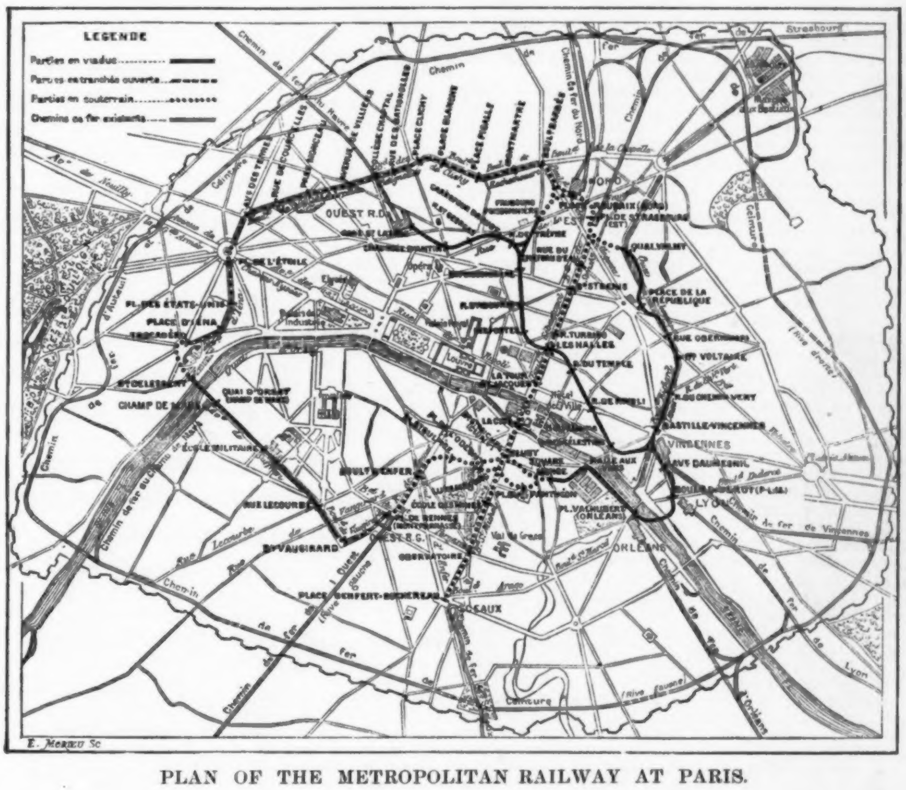
I have now completed, in, I fear, a very imperfect manner, the task I assigned to myself, and have endeavored to present to you a general view of physical science, to show how its several branches are interwoven, and how from every one of them you may gather valuable fruit. Some may look upon the questions I have brought before you as of little practical importance. But in this they are mistaken; for nothing has led to more technical improvement than a knowledge of the laws of Nature, and nothing has led to greater practical mistakes and more erroneous delusions than the ignorance of those fundamental principles of science which underlie all successful invention. Theory must come before experiment; for, without some theory, how could the imagination suggest the experiment, which is only a smaller form of practice? It is essential, therefore, that the theory should be a true and not a false one; and this—the separation of the true from the false—is the object of scientific training. For men so busily engaged as you are, it would be impossible to pursue to any length all the sciences I have mentioned: but it is easy to attain some knowledge of them all, and then, selecting one, or a section of one, to study that more deeply.

But I will not condescend to base the claims of science upon mere material benefits. I will not "coin the heart" of Science "into drachmas." I will appeal to your higher instincts; remembering that, beyond and above being engineers, you are *men*. You are endowed with intellects more or less cultivated. As food and exercise are necessary for the body, so are knowledge, reflection, imagination, necessary for the mind. In the study of the great organic laws we have discussed, you will find both nutriment and healthy exercise for the intellect. The more you know, the more you will wish to learn; the greater your attainments, the more deeply will you be sensible of how much you have yet to attain. The higher you climb, the clearer air you inspire, the stronger you become for new exertion; every breath giving fresh life as every step adds new vigor—earning for yourselves a wholesome joy, as you afford to others a wholesome example. As you rise, the great panorama unfolds itself more and more before you; and as you contemplate the variety yet unity, the complex results of simple causes, the infinite gradations of light and color that are composed from a few elementary hues, the apparent dissociation and the real union of nature's laws, you will enjoy the most magnificient material prospect that ever gladdened the eye of thinking man.

THE PARIS METROPOLITAN RAILWAY.

THE Paris Metropolitan railway, which has recently been conceded by the Minister of Public Works to Mr. Christophle, the governor of the Credit Foncier, will comprise four distinct lines, viz., an internal circle—a continuous line 12 miles in circumference, two-fifths of which will be aerial, while the balance will run underground or through open cuttings—and three transverse lines, along with junction lines.

The Internal Circle.—This line will start from the Champ de Mars, cross the Seine, pass underground under Delessert Boulevard, run around Trocadero Place, follow Jena Avenue in an open cutting, pass under Etoile Place, and follow Wagram Avenue and the external boulevards in an open cutting under the counter-alleys as far as to Barbes Bouvelard. Starting from this point, it will leave the external boulevards, pass underground beneath Magenta Boulevard and Roubaix Place, where there is a station that connects with the Railway of the North, and then reach the Station of the East.



PLAN OF THE METROPOLITAN RAILWAY AT PARIS.

After this the line will run as a viaduct along the Saint Martin Canal as far as to Republic Place, where it will make a bend to connect with the latter.

It will reach the Bastille through Republic Avenue and Richard Lenoir Boulevard, and then run to the Lyon station. From here it will run across the Seine above Austerlitz bridge, pass along St. Bernard quay, and turn through Fosses St. Bernard Street toward Monge Street.

At Monge Square it will run underground again, pass under Mt. St. Genevieve near the College of France, take Ecoles Street, cross St. Michel Boulevard near the Cluny Museum, pass under Odeon Place, under Garanciere Street and under Rennes Street, where it meets Enfer Boulevard, touch the Montparnasse station, follow Vaugirard Boulevard, and, after first following open cuttings and then becoming a viaduct, will reach the approaches to Lecourbe Street. Finally, as a viaduct, it will follow Suffren Avenue, and thus rejoin the Champ de Mars.

Transverse Lines.—(1.) From the St. Lazare Station to Roubaix Place. The viaduct will start from St. Lazare Station, cross Caumartin Street, and Chaussee d'Antin Street near the Opera House, run parallel with Lafayette Street up to the Drouot cross roads, and then pass underground beyond Rocroy Street. The junction with the circular line will be subterranean, and under St. Vincent de Paul Street. The length of this line will be about one and a half miles, plus 1,197 feet of junction line.

(2.) From the Drouot cross road to Daumesnil Avenue. This line will branch from the preceding by two junction lines, one starting from the Trevise Street station and the other from the Drouot station, and the two uniting just beyond Poissoniere Boulevard. It will run as a viaduct parallel with Montmartre Street, and bend and run parallel with Rambutea Street to the Temple Quarter, cross Rivoli Street near the City Hall, run along the Celestins quay, cross the Arsenal basin, and end in two branches, one running over the Vincennes line and the other toward Richard Lenoir Boulevard. The length will be 2¼ miles, inclusive of junction lines. There will be four tracks.

(3.) From Strasbourg Place to Denfert Rochereau Place.

This line will run underground under Strasbourg, Sebastopol, and St. Michel Boulevards, Observatory Avenue, and Denfert Rochereau Street. It will pass under the two branches of the Seine, and will connect with the circular line upon the right bank by two branches near Strasbourg Place, and upon the left bank to the east toward Monge Street by a curve running around the Sorbonne to Pantheon Place, and ending at Monge Square, and to the west, toward St. Sulpice Place, by a curve passing behind the Odeon. Total length, 4 miles.

The stations will be 64 in number: 28 in the viaducts, 15 in the open cuttings, and 21 in the tunnels. The accompanying map gives a complete designation of them.

The three first lines, which will suffice to connect the principal points of the city and suburbs, will have to be completed before 1889.—*La Nature.*

TESTING MACHINE AT WATERTOWN ARSENAL, MASS.

By J. E. HOWARD, Engineer in Charge.

THERE are three classes under which the tests made at Watertown Arsenal may be considered:

1. Tests made for the Ordance Department and other departments of the Government.
2. Tests made for private parties.
3. Industrial tests.

The first class includes those tests made on the physical properties of all material used for ordnance construction and the experimental elucidation of those problems associated with gun work.

The second class of tests are made for engineers, manufacturers and consumers of structural material, and relate to the quality of the metal examined in the sample bar and in full-sized members. The results of these tests are made known only to the parties on whose account the work is done. All other tests are reported annually to Congress, and published as a public document.

The industrial tests comprise both an examination of the qualities of the metals and their strength in various combinations, also the development of the principles and laws which govern the strength of complicated structures.

The principal lines of investigation being carried on are some extensive tests of bridge columns; riveted joints in both iron and steel plate; material subjected to long continued service; brick piers; wooden columns; tests of hot bars of wrought iron, cast iron and steel.

Referring briefly to the industrial tests, the following results may be metioned as embodying certain facts more or less at variance with generally accepted notions on the strength of materials.

The column tests have shown the resistance of ordinary forms of built posts in different cross section dimensions and lengths.

The tendency of compression tests is toward that improvement in design and workmanship by which a re-

sistance equal to the elastic limit of the material is reached, whether the column be longer or shorter.

The manner of failure indicates a practical limit to columns in terms of their diameters, long posts failing by sudden springing after the deflection has reached a small amount, at once reducing the resistance 40 per cent. or more; whereas, with shorter posts there is no sudden loss in strength; the deflection takes place gradually with a gradual reduction in resistance.

In the tests of riveted joints their behavior is observed and micrometer readings taken on the specimens from the first loads up to the time of rupture.

Generally speaking, the efficiency of joints in steel plates has been found higher than in iron; a joint of the former metal was tested which gave 90 per cent., the strength of the solid sheet.

It is inferred from a comparison of the behavior of joints and the solid metal, that in steam boiler practice it would be desirable to arrange the longitudinal seams of a cylindrical boiler nearly in lines from end to end, and not break joints in the different courses of sheets, as commonly done.

The comparative influence of punched and drilled holes on the strength of the metal is shown to depend upon the proportions of the test pieces. Numerous instances have been met in which the punched plates exceeded in strength the drilled plates. Punching produces an effect analogous to cold swaging or cold rolling, well known methods for elevating the tensile strength. In a joint with close pitched holes the effect of the punching is felt across the net section of the plate, and the result is increased tenacity; but in wide pitched holes there is a disadvantage in having hard metal at the holes by increasing the tendency to fracture in detail. Notwithstanding the greater strength in certain plates with punched holes over drilled ones, the drilled holes are generally to be preferred on account of leaving the ductility of the metal unimpaired.

Some locomotive parallel and main driving rods have been examined after 37 years' service, and having run 900,000 miles, and the metal found tough and fibrous, comparing favorably in tensile strength with good iron of to-day.

A series of tests with trader axles are in progress. Tests of the metal after 95,000 miles run show no change in its tensile properties. Observations made on the axles in place with the trader fully loaded gave deflections which corresponded to a maximum fiber strain of about 14,500 lb. per square inch, which is alternately one of tension and compression, making the total range of stress 29,000 pounds per square inch.

A number of bars of extra and double refined iron, which were fibrous in their fractures when first tested, have shown, when retested after different periods of rest, a gradual development of brittleness, until now, after a period of about four years, the fractures are almost wholly granular, with very little contraction in area. The tensile strength, in the mean time, has increased from 50,000 to upward of 60,000 pounds per square inch. Annealing restores the metal to its original fibrous structure as shown in the fracture, also to its original tensile strength. This illustrates the wisdom of annealing chains after long use. On the other hand, some wrought iron boiler plate, retested after three years' rest, was found to retain its primitive fibrous, lamellar structure.

Brick piers have been tested in sizes ranging from 8 inches to 16 inches square, and up to 10 feet in height, and laid in different kinds of mortar.

The moduli of elasticity of individual bricks, of the various kinds of mortar, and of the piers themselves, were determined. The difference in behavior of the mortar and bricks under compressive stress is sufficient to account for cracks in brick-work under certain pressures without attributing them to defective foundations. Common brick piers laid in lime mortar were found to have about 14 per cent. additional strength when joints were broken once in six courses over the ordinary method of breaking joints with each course. Laying the bricks on edge was found to increase the strength of the piers about the same amount.

Some observations on steel and wrought iron bars show a reduction in the modulus of elasticity, resulting from straining the metal beyond its primitive elastic limit. In this way the modulus of elasticity of a steel bar was reduced from 29,000,000 lb. to 17,000,000 lb. Rest restores the modulus to its original value, the wrought-iron bars displaying an ability to thus recuperate earlier than the steel. The full significance of this remarkable change is yet a matter of conjecture, but suggests the probability of its being the result of a molecular disturbance affecting the durability of the metal.

Preliminary tests have shown that bars of wrought iron at the so-called "critical" temperature or blue heat possess a tensile strength greatly in excess over the cold bar, the stresses being gradually applied and in direct line with the axis of the test piece.

Samples of different metals have been subjected to a hydrostatic pressure of 90,000 pounds per square inch, and afterward tested by tension, without showing any change in their strength or ductility. In cold-rolled metal we have illustrated the effect of pressure accompanied by flow, which elevates both the elastic limit and the tensile strength. In these cubic compressed specimens, pressure without flow is shown to produce no effect on the tensile properties.

While making these tests, the compressibility of water, carefully boiled to expel the air, under high pressure, was found to be considerable. The leather packings employed to seal the water in the hydrostatic cylinder during these tests worked well under a pressure of 117,000 pounds per square inch.

The testing machine is now worked to its full capacity, and there is a accumulation of work ahead. The Ordnance Department, U. S. A., has taken active steps toward procuring additional testing machinery to meet the increased demands of this work, and which will enable the large machine to be employed wholly on the tests of full-sized members, the smaller machines testing the smaller samples, thereby materially increasing the efficiency of the testing laboratory.—*Jour. Asso. Eng. Societies.*

A METAL that expands in cooling is made of lead, nine parts; antimony, two parts; bismuth, one part. This alloy can be advantageously used to fill small holes and defects in iron castings.

A MEAT CANNERY.

LISTEN to me, all people, a while, I've something I'd like to relate
Of progress made in a certain trade since the year of 'seventy-eight;
About that time 'most every line of canned meats on the market
All seemed to lag, hang back, and sag, for want of brains behind it.

Then Chicago's resident merchant king, from some of the Eastern groves,
Declared of it he'd take a hold, and handle without gloves.
Said he, "I will preserve meats, too, from strictly first-class cattle,
And in the course of a few years,' round the world my brand shall rattle;

For I'll put up naught but first-class goods, the can in which I'll make,
And solder it on the outside, too, that there be no mistake,
Nor ill effects of eating meat from contact with the tin;
Then, while the air the can's without, the meat is good within."

He slaughters cattle here and there, he counts by thousands daily,
And, when ready, sells and ships off to some foreign navy.
The steer knocked down, the butcher's knife the sticking-piece does tickle;
Then stripped of hide off—all and bone put down in fine, sweet pickle.

And when the meat is rightly cured, it's brought up to the coppers,
And cooked by steam for a certain time, then put before the choppers,
Who cut the meat of different size for various cans to suit,
And when they've chopped a goodly pile, they push it down the chute.

Here 'tis caught up by other men, put into a stuffing machine,
Which fills the can with the greatest ease, already so perfect and clean;
But should anything happen the stuffing machine, or the meat not go into the hopper,
A moment's work for the boy close by will shift the belt and stop her.

Out comes the can, the cap sealed on, and another one put in its place;
The vent is stopped, then overhauled, then off the next room to process.
Here 'tis put through the preserving course as fast as the men are able,
Then away it goes to another room, to take on its paint and label.

The cans are packed in boxes tight, the nails driven home with a whack,
Then out of the door, put in his own cars, close by on the railroad track;
And when these trains are loaded down, they're quickly got in motion,
And hauled down to the sea and sent in shiploads o'er the ocean.

Here 'tis sold to governments whose opinions never vary,
For canned meats always take the lead in every commissary.
These goods all find a prominent place in every household larder,
For behind this ponderous enterprise is the pushing P. D. Armour.

THE PRESIDENT'S ADDRESS TO THE MASTER MECHANICS' ASSOCIATION.

WE give below in full the excellent address made by President J. Davis Barnett at the opening of the Master Mechanics' Convention in Boston, on Tuesday, June 15.

LADIES AND GENTLEMEN: It is a real pleasure to meet with you and greet you once again. Your happy faces tell a tale of good health, of high spirits, and of ability to respond to and enjoy, not only the civic hospitality so kindly extended to us by this good city, but to appreciate all its other good things.

I have often expressed my personal feeling that Boston is the most charming city to visit on this continent. I regret that I was not a member, and therefore had not the pleasure of attending the convention that was held here fourteen years ago (1872), yet those who were—I know by their vivid recollections of that time—have most happy remembrances of the right hearty way in which our Association was welcomed, and its financial position then strengthened; and we believe that the warm words of welcome we have just heard from His Honor Mayor O'Brien are a genuine expression of Boston's feeling toward us.

I am glad to say our treasurer's and secretary's reports are encouraging; they show an unspent balance, and our membership has not lessened, although, to our sorrow and regret, since last we met, five members have gone over to the majority. May they rest in peace!

It is possible that the change of mileage from broad to standard, carried out during the last few days in the Southern States, may yet keep the members there resident so busy that we shall not see all of them this year. Should this unfortunately prove to be the case, I much regret that the dates should have fallen so close together as to make it impossible for all to attend this meeting, which I had hoped, and still shall hope, will not fall behind any previous one either in attendance, interest, or educational value.

That the ladies continue to favor us with their presence and kind smiles is a matter of happy congratulation, and they must not think my thanks are not real, and the words are feigned, even if they do come from a bachelor.

This morning, more particularly to our working and junior members, I wish to speak a few words on the "Uncertain in Locomotive Engineering," and how we can best reduce it. The certain is the concrete results of past experience; it is familiar, prosaic, and it fails to keenly interest or stir us; but that which is still uncertain, still undefined, the test or experiment our friend has in hand, the problem we are trying to solve—these unconsciously draw out our enthusiasm; as we thus hope to obtain one more point of indisputable fact, to make the foundation of our daily practice more firm, to take another and a closer grip on nature; and it is this continually obtaining, this breaking down of the barriers, this wider survey and clearer plotting of what recently was an unknown territory, that gives the growing interest to our profession and to these our annual reunions.

Critics (and not necessarily unfriendly critics) have said that individually in convention we make contradictory statements, and collectively our published proceedings are conspicuous by the absence of definite conclusions and formulated results.

It seems to me that there is small cause for wonder that statements appear to be contradictory, when it is considered how numerous are the differences in metal, in fuel (and can I add, in men?), how great the variation in service the materials are put to, and also over how many substances one word is stretched to cover. May I illustrate? We commonly use the words "soft coal" as if it were a single definite, almost elementary substance, ignoring the fact that the varieties from the same bed and seam are numerous, and that two specimens which chemical analysis shows to have practically equal percentages of the same constituents are seen to behave very differently when distilling on the grade, yielding different residues, as well as showing large variation in calorific power.

"Steel" is another common instance in illustration. What a bewildering variety of substances, with highly differentiated qualities, does this little word cover, and how wide the differences necessary in its treatment, from tool steel, injured by high heat, to boiler plate, which is made dangerous to human life if it has been worked at low or colorless heats!

Therefore, when circumstances so greatly differ, and the use of a similar word is so far from implying that a similar substance is referred to, should it be a matter of surprise if a member's statement that so and so is *black* is directly followed by another's that it is *white*? The thought I desire to impress upon you is the necessity for noting and fully stating all the qualifications or circumstances limiting the observed fact; we shall then see these apparently diverse statements fall into parallel lines, and the conclusion (in many, if not most cases, indorsed by the majority) shows that it is *gray*, or a mixture of both black and white.

All the circumstances qualifying, influencing or seemingly only coincident with an observed experiment, should be noted. For the trend of modern scientific research is to show that it is the small circumstance (so small and apparently so trivial as to be overlooked for years) that proves to be the missing link, the missing ward in the key that unlocks the puzzle, showing the complete, yet simple, operation of cause and effect.

We need to educate the closely observant eye that will not be deceived by superficial appearance into lazily concluding that the apparently familiar result is exactly the old, well-known incident, with nothing but the old lesson to teach and the old law to enforce.

Hence the value of seeing any fact in physics, or any experiment, with our own eyes; and also, because of the liability to usual deception of seeing the same thing through the eyes and mind of one or more independent observers, of noting the points brought out, that to them seem most prominent and closely related, the sequence or order in which they follow, and their relative proportion to and influence the one on the other.

We can, I think, best get into this good habit—considering the pressing limitations due to time and business calls—by free mutual exchange of experiences, and our Association is based on that belief; but each statement we make, to be current at its full value, must be specific—something more than a flat contradiction, or an "I don't think so." Let us strive to give the *why*, as well as to state the naked fact that in our observation it *is* so.

We can by striving get the *why*, for it is certain that regularity and eternal law reign throughout the most diverse results. This is our unshaken foundation. If results seem to vary, it is because we either do not know, or have not observed, the conditions that insure success. The defect is in ourselves, for nature's laws know "neither variableness nor shadow of turning." Open eyes, unblinking observation, energy, and freedom from foregone conclusions, are necessary; not that nature is deceitful, but she does not disclose her hidden charms except to those who ardently seek them.

Foregone conclusions are a fruitful source of error. Let us for an illustration turn again to steel, used successfully to sustain rolling friction, yet a failure when inferential reasoning led to its application to resist rubbing or sliding friction. To make a fair trial of the rolling of steel tires on steel rails was to recommend the exclusive use of steel—it did its work so well, had so long a life, so little frictional resistance, and possessed such high powers for resisting abrasion; yet the attempt to *slide* one polished steel face upon another, as an eccentric inside its strap, or a cross-head upon its slide-bar, has not to-day reached the stage of successful experiment.

It is now clear that any inference obtained from experiment in rolling friction between metals will not apply to sliding friction; to think you can do so is a futile attempt to get at nature's law by a foregone conclusion. The same may be said of any attempt to apply resistance rules deduced from friction at low velocities to practice at high velocities, and it was unwise to expect that boiler plate with 1-300 part of carbon would behave the same as if it contained but the 1-700 part, or even a more minute fractional part of phosphorus.

These are trite examples, but they the better serve to emphasize the necessity for clear discrimination between things that seem to differ (if at all) but very slightly, and also to remind us to properly qualify and elucidate our statements, and to closely observe the small things.

Dr. G. Gore has shown how widespread and inclusive

are the influences of seemingly small causes. Thus warmth, or even moderate pressure, applied to a piece of steel definitely and in most cases measurably altered its "length, breadth, thickness, molecular arrangement, atomic distance, specific gravity, cohesive power, adhesion to liquids, elasticity, temperature, specific heat, latent heat, thermic conductivity, thermo-electric power, electric conduction, resistance, magnetic capacity, chemical and chemico-electric actions, and a number of other properties simultaneously," so that his vivid experiments almost produce the impression that this metal is endowed with vitality.

Thus, although we need not pay attention to all these points, you see that if we treat metal as inert, and stable under all except extreme variations of temperature and pressure, we shall be deceived, and find our attempted application of experimental results to daily practice very disappointing; but if we carefully discriminate and notice the small signs we shall make fewer mistakes, have less failures in daily work, do something to lessen the still wide field of the uncertain, and increase the present narrow swath of the known and certain.

May I now thank you for the kind and considerate attention with which you have listened to this dry prosing? Remember, in extenuation, that it is the nineteenth year you have listened to an address from the chair, and the possibilities of something new and interesting to all seem—at least to me—very limited.

AUTOMATIC REGISTRATION OF THE HEAT UNITS DISENGAGED BY A LIVING BEING.*

By A. D'ARSONVAL.

IN former communications I have called the attention of the Academy to the importance of calorimetry in physiology. The thermometer, when used alone, is not capable of showing us the variations in thermogenesis. This is due to the fact that an animal does not radiate after the manner of an inert body.

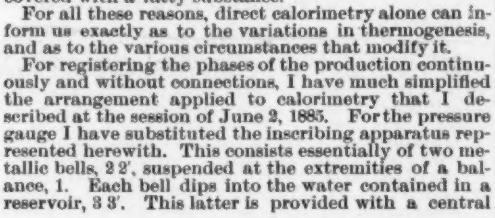
Thanks to the vaso-motor nerves, the loss of heat through the periphery of the body varies at every instant, according as the capillaries of the cutaneous surface are more or less dilated. A fall in the central temperature does not always correspond to a production of less heat, and conversely, as I have shown in the case of varnished or oiled animals. The central temperature of a rabbit rubbed with oil lowers considerably, and yet this animal, when placed in the calorimeter, disengages two or three times more heat than when in a normal state.

Birds, whose central temperature is from 4° to 5° higher than that of mammals, do not, weight and surface being equal, produce more heat than the latter, as I have, contrary to the accepted opinion, shown by the calorimeter.

On another hand, I have shown that, at an equal temperature, the emissive power of the human skin may vary from simple to triple, according as it is dry or is covered with a fatty substance.

For all these reasons, direct calorimetry alone can inform us exactly as to the variations in thermogenesis, and as to the various circumstances that modify it.

For registering the phases of the production continuously and without connections, I have much simplified the arrangement applied to calorimetry that I described at the session of June 2, 1885. For the pressure gauge I have substituted the inscribing apparatus represented herewith. This consists essentially of two metallic bells, 2 2', suspended at the extremities of a balance, 1. Each bell dips into the water contained in a reservoir, 3 3'. This latter is provided with a central



tube, 4 4', which exceeds the level of the water, and which converts the corresponding bell into a little gasometer of extreme mobility. The interior of each bell is connected, through the central tube, 4 4', with the cavity of one of the air calorimeters, 9 9'. The calorimeters that correspond to each bell are identical.

If a source of heat happen to warm one of the calorimeters, the air will expand and lift the corresponding bell to a height that serves as a measure of the heating.

If the two calorimeters be heated equally, the two bells will be in equilibrium, and the balance that supports them will not change position. By this fact, the apparatus is protected against variations in temperature and external pressure, as in the compensating pressure-gauge apparatus. The water reservoirs communicate with each other through a lateral tube, 5, which makes their levels identical.

In order to render the apparatus a registering one, the beam, 1, carries a lever, 6, terminating in a pen that traces a line upon a vertical cylinder, 7, which makes one revolution every twenty-four hours. The length of the lever and capacity of the bells are such that the pen rises 0·01 meter per 1 heat unit per hour disengaged in the apparatus. It is possible, however, to obtain any sensitiveness that may be desirable.

A tromp (not shown in the figure) causes a continuous current of air to circulate in the apparatus, and, at the same time, it is possible to estimate the oxygen absorbed and the carbonic acid given off by the animal under experiment, according to processes that I have described in my various communications since 1878.

We can thus pursue an experiment for days at a time, and for weeks even, without having to make any correction.

As the registering cylinder makes one revolution in eight days, no surveillance is necessary, and it is owing to this that I have been enabled to undertake a continuous calorimetry of inanition in the Guinea pig, rabbit, and hen.

One can, at will, perform absolute experiments with an isolated animal, or comparative ones, by placing a different animal in each calorimeter.

This instrument is easily manipulated, and answers, I think, all the requirements of physiological calorimetry, in which comparative measurements often have more importance than absolute values.

Thermo-Electric Calorimeter.—The air calorimeter requires about from a half to three-quarters of an hour to get into equilibrium and furnish a positive indication. This is quite a long time when it is a question of a lecture experiment. This is why, in my lectures of this year, I have described to my class another arrangement, which shows a large audience the calorimetric power of an animal in the space of five minutes. The process, in the main, is merely a variation of the preceding, and necessitates the use of a galvanometer.

The air calorimeter just described is a differential air thermometer; but the thermo-electric one, as its name imports, is a differential electric thermometer. It consists of two conjugate (copper-iron) thermo-electric parts. One of these (the calorimeter) is hollow, and envelops the animal, while the other enters the surrounding air.

The animal radiates through the hollow calorimeter and heats it, and the galvanometer shows by its deflection the excess of temperature of the metal over that of the surrounding air.

A luminous ray projected upon the mirror of the instrument permits the largest audience to follow the progress of the experiment upon a graduated scale that the ray traverses.

Under such circumstances, a thermic equilibrium is very quickly obtained, and it is with great accuracy that we measure the instrument's heating, which is here less than in the air calorimeter. This is a very favorable feature, as the thermogenesis of the animal under experiment is not interfered with.

We might, if need were, inscribe the galvanometer's deflections by photography, as I do in other experiments; but this would be a complication that we would prefer to avoid in practice, through the use of the air calorimeter instead.

The thermo-electric calorimeter is capable of rendering great services in the study of the production of heat in the isolated tissues of the organism submitted, or not, to artificial circulation.

By the aid of this extremely sensitive instrument, we can ascertain and measure the production of heat in the lower beings, and in cold-blooded animals, such as batrachians, fishes, and others.

The thermo-electric calorimeter may be of microscopic dimensions and yet preserve its sensitiveness. I have made some that were just large enough to contain an insect or a larva.

* Note presented to the Academie de Sciences, April 5, 1886.

THE ABSORBABILITY OF FATS OR ANALOGOUS SUBSTANCES BY THE SKIN.

Translated from the *Journal de Medicine de Paris* by E. B. ANGELL, M.D., Rochester, N. Y.

THE celebrated dermatologist Dr. Unna has shown that the more readily a fatty substance absorbs water, the more rapidly is it itself absorbed by the skin. He has found out what are the relative amounts of water that fatty substances will take up, such as vaseline, lanoline, and various mixtures. The complete table of the results of his experiments is given below. It is of interest through indicating the relative value of the various substances used as inunctions or as vehicles for external medication.

One hundred parts of the following substances absorb:

			Parts of Water.
1.	Vaseline		4
2.	Lard		15
3.	Benzoated lard		17
4.	Almond oil	70	23
	Yellow wax	30	
5.	Olive oil	70	26 to 31
	Yellow wax	30	
	(According to the age of the oil.)		
6.	Cod-liver oil	70	28
	Yellow wax	30	
7.	Cod-liver oil	70	32·3
	White wax	30	
8.	Linseed oil	70	41·3
	Yellow wax	30	
9.	Linseed oil	70	48·5
	White wax	30	
10.	Oleic acid	70	50·5
	Yellow wax	30	
11.	Oleic acid	70	60
	White wax	30	
12.	Olive oil	60	16
	Turpentine (oleo-resin)	10	
	Yellow wax	30	
13.	Olive oil	65	19
	Resin	10	
	Yellow wax	25	
14.	Mutton tallow	70	27
	Olive oil	30	
15.	Lard	80	14
	Spermaceti	10	
	Olive oil	10	
16.	Lard	50	28
	Spermaceti	10	
	White wax	10	
	Olive oil	30	
17.	Olive oil	70	32·6
	Spermaceti	15	
	Yellow wax	15	
18.	Olive oil	70	39·5
	Spermaceti	15	
	White wax	15	
19.	Lanoline		105

According to the above table, mixtures containing white wax absorb more water than those prepared with yellow or unbleached wax. This may be due to the fact that white wax is more or less acid, and this opinion seems to be confirmed by the greater absorbability of mixtures containing oleic acid.—*Buffalo Med. and Surg. Jour.*

VERTIGO, AND ITS TREATMENT BY BLISTERS.

DR. CHARLES E. WILLARD, of Catskill, N. Y., writes: "Having had under my professional care, during the past winter, an unusually large number of cases of stomachal vertigo, I feel constrained to place upon record some of them, as they differed somewhat in their most prominent symptoms from those usually recorded as classical. I hope that that which caused me much vexation of spirit will prove of service to some other members of the profession who, like myself, have been driven to the wall by these often stubborn and intractable symptoms.

"To be brief, then, I will begin at once with some of the symptoms as witnessed in Mr. J——, aged forty-two. The first attack occurred while upon a ladder. The sensation, as he graphically described it to me, being as though an earthquake was about taking place, the house and the ladder moving as though on the waves of the ocean, rolling and pitching, but always with the roof ahead, and never turning sideways; a sensation of fear, and a peculiar sick or faint feeling at the pit of the stomach: the knees also appearing to lose all their strength; during all this time he was conscious there was no earthquake, or that the house was anything but standing firmly. His arms were not affected by the general weakness, and by holding himself closely to the ladder he avoided falling; and in a short time, the symptoms passing off in a measure, he was enabled safely to descend the ladder. There were no further developments that day; but the next morning, upon awakening and turning upon his left side in the bed, he immediately had a return of the dizziness, only this time the bed seemed to go pitching around the room, always the foot of the bed first (ahead), as though it were floating rapidly upon a huge wave of water, never turning over or upon its side, but always remaining level. After resting for a while upon the back, the symptoms in a measure subsided, but upon again turning upon the left side, there was a reappearance of all the symptoms just described, with the addition, this time, of a shower as of black soot falling before the eyes. All subsided again in a short time by turning upon the back, and after taking a short nap he carefully turned upon the right side and was enabled to get up, slowly dress himself, and eat a light breakfast.

"During the next ten days these symptoms occurred at irregular and uncertain intervals, accompanied by headache of a peculiarly distressing character, completely preventing any kind of labor, either physical or mental; there was some slight hesitancy in the speech; great mental depression, as though upon the border of some impending evil; during this time walking was very uncertain; upon making any effort to turn to the left he was likely to fall, or stagger off the sidewalk into the street. Whenever it was necessary to turn a corner to the left, it was necessary to walk to the end of the curb, make a slow and complete circle to the right the whole width of the sidewalk, and then go ahead again.

"In another case, Mrs. W——, the symptoms followed an attack of erysipelas, and for two days and nights there was frightful headache, the patient remarking as though her head was in a vise, the pressure being upon each temple. During these forty-eight hours there was constant nausea, with frequent vomiting and retching, nothing but froth and mucus coming from the stomach, as there was no food taken during this time, the pain meanwhile being most severe upon the right side of the head. The patient was confined to the bed ten or twelve days. The dizziness was so great that she could not sit up, even in the bed, without producing faintness and vomiting. During all this time there was a constant roaring in the head as of a waterfall, a ringing in the ears, more especially the right, together with pain, and before each eye a large wheel, revolving rapidly, with broad spokes with deep notches between, the wheels apparently approaching each other and then receding constantly. Upon looking up she could read the print in a newspaper, but upon looking down everything was a blot and dizziness.

"This case, unlike that of Mr. J——, had a recurrence of the dizziness upon looking or turning to the right, even lasting some days after she was able to be moved from the bed. There was a constant and severe pain at the back of the neck, more especially upon the right side, together with a fullness and throbbing which could be seen and felt; the pain extended down the whole length of the spine, and alternated with the dizziness. When the head was most dizzy, the pain in the back was less severe, and *vice versa.*

"In another case, that of Mrs. H——, the dizziness was always accompanied with a dull, aching pain in the left lung. The pain did not interfere with the breathing, and upon auscultation the lung was found to be free from disease of any kind. The pain in the lung always disappeared with the dizziness. In this case the patient was often awakened suddenly in the night, the dizziness and pain already present, when the bed, room, and furniture would apparently be pitching about in the greatest confusion. These distressing symptoms would last from one-half to one hour and then subside, leaving a peculiar feeling in the head not to be described, with soreness and pain, as though from some severe side pressure. This also would wear off in the course of twenty-four or forty-eight hours, sometimes, but not always, followed by vomiting. During the continuance of the symptoms, no food could be taken or retained by the stomach.

"In another case, that of a gentleman, Mr. H——, aged fifty-five, the attack would occur so suddenly that on several occasions he fell upon the floor, and was unable to arise for some time. I might go on and mention a number of other cases, each having some peculiarity of its own in common with the general symptoms, but I have already exceeded the original limit of this paper.

"Now for the treatment. After trying the various remedies recommended in the text-books, and not deriving the results I desired, I applied *blisters* to the *neck*, and in some cases, when the pain in the back was severe, all the way down the spine. The result of the blistering was very satisfactory, improvement beginning almost immediately, and my patients are to-day attending to their ordinary duties. Of course I did not neglect, but continued, general treatment. I think that the use of blisters in these cases cannot be too high-

ly recommended, even though we cannot explain their *modus operandi*.

"In the treatment of these cases I used a *blister* which does not contain cantharides, and therefore is free from the exceedingly unpleasant complication of strangury. These blisters, or 'issue plasters,' as they are called, have proved very satisfactory in my hands, not once producing an unpleasant symptom—they blister quickly, without pain of any consequence, and by returning them to the blistered surface an issue can be kept up for any desirable length of time—and, as I remarked above, without the slightest fear of strangury occurring as a complication. I greatly fear that with the general practitioner the beneficial effects of judicious blistering, in these and other similar cases, are oftentimes lost sight of in dread of the unpleasant symptoms produced by cantharides."—*Medical Record.*

THE CREEPING AVENS.

(GEUM REPTANS.)

A GOOD idea of the kind of plants most suitable for overhanging ledges in rock gardens may be gleaned from the accompanying illustration. Many plants in the rose family have characters akin to that shown, but, as in the case of Potentilla anserina and many others, as well as in Fragaria, the trailing habit is their only recommendation. In the present instance, however, we have not only a handsome trailer, but large flowers, of a good yellow color, and very striking during the early spring months. G. montanum, a nearly allied species common in gardens, is generally grown on flat surfaces or on slightly raised mounds of earth

THE CREEPING AVENS (GEUM REPTANS). FLOWERS YELLOW.

or stones. G. reptans, however, may be used with great advantage in a variety of ways, for few rockeries, however small, are without places in which its trailing habit could be shown off to good effect; we prefer an inclined wall or bank of rough stones for plants of this class. It may also be grown with good effect in baskets or pots for hanging on verandas or in cool houses. It flowers with or about the same time as Campanula garganica, and the two placed alternately present a fine appearance. G. reptans rarely exceeds six inches in height; one flower is produced on each stem from one inch to two inches in diameter, and of a fine, rich yellow color. Each plant produces one or two runners, which may be used to almost any extent for purposes of propagation. Its seeds have long feathery tails about the same length as those of G. montanum, but jointed or curved at the end—not straight, as in that species. It is a native of South Tyrol, etc.—*K., The Garden.*

INFLUENCE OF FORESTS ON THE CLIMATE OF SWEDEN.*

A VALUABLE report on this subject has been prepared by Dr. H. E. Hamberg, and printed as an appendix to the Report of the Forest Commissioners of Sweden for the year 1885. The observations were commenced in 1876, on the principles established by Dr. Ebermayer in Bavaria, but Dr. Hamberg soon found that the mere comparison of the results obtained at the forest station with those yielded by its sister station in the open country was insufficient to bring out all the peculiarities of forest influence, and accordingly he added a third class of station, situated in a clearing in the forest itself (*öppen plats i skogen*). The various results of these observations are discussed in a very exhaustive manner, and we must refer those interested in the subject to the report itself. The author's conclusions, however, are very interesting, and are reproduced here in full:

"Our researches do not allow us to determine whether the presence of the forests on the whole contributes to increase or diminish the quantity of heat in the atmosphere, that is to say, to raise or lower its temperature. In fact, we have been entirely unable to take into account either solar radiation or the radiation from the needles† and the points of the trees. Until we are able to ascertain the quantity of heat which escapes from these surfaces, and its relation to that escaping from other surfaces, it is quite impossible to determine with certainty the influence of the forest on such an important subject as the mean temperature, and must confine ourselves to approximate estimations. Among the various surfaces which are met with in Sweden the most important are assuredly water, bare ground or rock, soil covered by herbage, and finally forest. Neither the surface of the lakes and sea nor the bare soil of town streets has any resemblance to the forest; the climate of the latter bears no similarity to a maritime climate or a town climate. A forest may best be considered as an instance of vegetation on a gigantic scale, as is evident from the low temperature of the ground under the trees and the freshness of the air in summer, especially in the evening and at night-time, thus affording evidence of active radiation. In this case the forest would be a source of cold rather than of heat. But here we are simply dealing with suppositions.

"From this point of view a forest is distinguished from all the other surfaces we have mentioned, in that it extends into a stratum of air lying far above that in which man lives and carries on all of his occupations which depend on climate, such as agriculture, etc. It should follow from this that whether the annual result of the presence of a forest be an excess or a defect of heat, the one or the other should, thanks to the winds, be communicated to a greater mass of air, and be less sensible in the stratum close to the ground. The thermic properties of other surfaces are more immediately available in the lower stratum, and consequently, from the practical point of view, exert a greater influence on the temperature of the earth and of its immediate vicinity.

"If, then, we confine our consideration to that which from the practical point of view is perhaps the most important, the influence of forests on the state of temperature in the stratum in which man generally lives, in so far as this can be determined in the ordinary way by thermometers, I think that our reply for this country (Sweden) will be less uncertain, and it is as follows:

"In the districts of our country which are open and are cultivated, during the annual interval of cultivation a forest lowers the temperature of air and soil during evenings and clear nights, restricting the period of daily insolation, and thereby checks vegetation.

"The other influences of forests on temperature are either so slight that they possess no practical importance, as, *e. g.*, the moderation of cold in winter, or else are of such a character that they elude the ordinary mode of observation by thermometers. Among the effects of this nature we may mention the well-known fact that forests afford shelter against cold and violent winds to vegetation which would suffer from these winds, or to objects whose temperature is higher than that of the environment, as for instance the human body. It is in this last respect that the Swedish saying is true, namely, that 'the forest is the poor man's cloak.' In certain cases it may also yield protection against the cold air or fog which on cold nights comes from districts in the vicinity which are visited by frost. The advantages on the score of temperature derivable from the forest may therefore be considered to resemble that obtainable from a wall, a palisade, a hedge, or any object of that nature.

"On the one hand, a forest, where it is close at hand, offers mechanical protection against cold and violent winds. On the other hand, it does injury either by retaining the solar heat required by crops or by lowering the temperature of the soil during clear nights, and thus favoring the development of hoar-frosts. At a distance forests have no sensible influence on the climate of Sweden.

"If we wish to put these results to a practical application, it is impossible to say in general whether one should, or even could, clear the forest without injuring agriculture. But it appears that as regards the temperature, if we disregard the utility of forests in other directions, we might make extensive clearances without any prejudice to agriculture. It is certainly not a mistake to say that our best cultivated districts are the freest from wood, nor is it a mere chance that the harvests are, on the whole, more sure in the open country than in the forest. In the event of a bad harvest, it is, as I well know, the wooded districts which have suffered most. At the same time, I must at once admit that these provinces are also influenced by other powerful physical factors, possibly even more active than forests, such as an elevated situation, a bad soil, the presence of swamps, etc. But nevertheless it appears to me, after all that has been said in the preceding pages, that the forest has some bearing on the subject.

"At the present day, the words spoken 130 years ago by Pastor P. Hogstrom, and at that time member of the Swedish Academy, are very generally applicable, inasmuch as it has been found that cultivation can to a great extent remove from a district its tendency to hoar-frost; this same result has frequently been obtained by draining or by clearing the forests, particularly those of deciduous timber, where the fogs, especially those which bring on frosts, appear to have their origin and their aliment. On the contrary, a pine forest is an excellent shelter against cold, especially when it can stand between the country and marshes or surrounding districts where the cold has its rise. If, however, the forest interferes with sunshine and with wind, it should be cleared. It results, therefore, that while in some districts the clearing of a forest has been beneficial in averting hoar-frost, in others the result has been directly the opposite."

* "Om skogarnes inflytande pa Sveriges klimat." From *Quart. Jour. Roy. Met. Soc.* for April, 1886, communicated by Mr. R. H. Scott, F.R.S. —*Nature.*

† The forests dealt with were entirely of pines and firs.

[NATURE.]

VEGETATION OF SOUTH GEORGIA.

ON Tuesday, January 17, 1775, Capt. Cook landed on this remote island, which is situated about 1,000 miles east of Cape Horn, in about 54° S. lat. and 37° W. long., and took possession of it in the name of King George the Third, after whom he named it. Capt. Cook landed in three different places, and the ceremony of adding the island to the British dominions, he informs us, was performed under a waving of colors and a discharge of small arms. Whether any British subject has ever set foot on it since that day I know not; but the description of the island by its famous discoverer was not likely to tempt any one to go out of his way with that object in view. Although lying only as far south of the equator as York is north of it, South Georgia is covered, in the higher parts at least, with permanent snows and glaciers, and is altogether of a most wild and desolate aspect. Large masses of ice were continually breaking off from the perpendicular cliffs and falling into the sea with a noise like cannon. "The inner parts of the country," says Cook, "were not less savage and horrible. The wild rocks raised their lofty summits till they were lost in the clouds, and the valleys lay covered with everlasting snow. Not a tree was to be seen, nor a shrub even big enough to make a toothpick. The only vegetation we met with was a coarse strong-bladed grass growing in tufts, wild burnet, and a plant like moss, which sprung from the rocks."

Animal life, however, was more abundant. Seals were plentiful, and the penguins the largest ever seen by Cook; some which were taken on board weighed from twenty-nine to thirty-eight pounds. Eight kinds of "oceanic birds" are enumerated, and one, a yellow bird, was found to be delicious food. All the land birds observed were "a few small larks." From Cook's narrative it appears that Forster, the botanist, was one of the landing party, hence it might have been expected that few flowering plants would have escaped observation, especially as the visit was made in January, the midsummer of the southern hemisphere. Forster himself states ("Observations made during a Voyage round the World," p. 16) that South Georgia is an isle of about eighty leagues in extent, consisting of high hills, none of which were free from snow in the middle of January, except a few rocks near the sea. And he adds that there was no soil except in a few crevices of the rocks.

No further information respecting this island has been published, so far as I am aware, until since the return of a recent German expedition, which made the island one of its stations for meteorological and other observations. When collecting the materials to illustrate the flora of the very much broken coldest southern zone of vegetation for the "Botany of the Challenger Expedition," I had to be content with Cook and Forster's very meager accounts of South Georgia; but from the published northern limits of drift ice in different longitudes in the southern hemisphere, it was not expected that South Georgia possessed much more than the scanty flora they attributed to it, though Macquarie Island, in the same latitude, and nearly in the longitude of New Zealand, was known to support a comparatively luxuriant vegetation. Dreary and barren as it is, however, South Georgia is not so bad as it has been painted. The officers of the German expedition spent nearly a year on the island, and appear to have explored it thoroughly, botanically and otherwise. During this period the atmospheric pressure was subject to extraordinary fluctuations, the extremes exhibiting a difference of 64 millimeters, or a fraction over 2½ inches, while the range of temperature during the same period was only 48·6° Fah., or in round numbers from 8° to 57° Fah.; thus showing the freezing-point to be nearly midway in the range. The actual mean temperature of the year was 35·06° Fah.; of June, the coldest month, 25·6° Fah.; and of February, the warmest month, 41·6° Fah.

With regard to the flowering plants collected in the island by Dr. Will, one of the officers of the expedition, we are indebted to Dr. Engler for an enumeration of them in his *Jahrbucher*, vol. vii., p. 281. They are thirteen in number, and their general distribution is so extremely interesting that I may be pardoned for giving it in detail:

1. *Ranunculus biternatus*, Sm. (Ranunculaceæ).—Fuegia, Falklands, Tristan d'Acunha (?) Marion and Kerguelen Islands.
2. *Colobanthus subulatus*, d'Urville (Caryophyllaceæ).—Fuegia, Campbell's Island, New Zealand, and Alps of Victoria, Australia.
3. *Colobanthus crassifolius*, d'Urville (Caryophyllaceæ).—Fuegia and Falklands.
4. *Montia fontana*, L. (Portulaceæ).—Fuegia, Marion, Kerguelen, Campbell's Island and widely diffused.

5. *Acæna adscendens*, Vahl (Rosaceæ). — Fuegia, Marion, Crozets, Kerguelen, Macquarie Islands, and New Zealand.
6. *Acæna lævigata*, Ait. (Rosaceæ).—Fuegia.
7. *Callitriche verna*, L. var. (Halorageæ).—Fuegia, Marion, Kerguelen, Heard Islands, New Zealand, and widely diffused.
8. *Juncus novæ-zealandiæ*, Hook. f. (Juncaceæ).—New Zealand.
9. *Rostkovia magellanica*, Hook. f. (Juncaceæ).—Andes, Fuegia, Falklands, and Campbell's Islands.
10. *Aira antarctica*, Hook. f. (Gramineæ).—Fuegia, Falklands, and Kerguelen Island.
11. *Phleum alpinum*, L. (Gramineæ). — Magellan's Straits, and widely dispersed in the cold regions of the northern hemisphere.
12. *Festuca erecta*, d'Urville (Gramineæ).—Fuegia, Falklands, and Kerguelen.
13. *Poa flabellata*, Hook. f., syn. *Dactylis cæspitosa*, Forst. (Gramineæ).—Fuegia and Falklands.

From the collector's remarks, appended by Engler to each species, it appears that some of the foregoing plants flourish luxuriantly in South Georgia, especially the species of *Acæna* (the burnet of Cook's narrative), and *Aira antarctica* and *Poa flabellata*. The *Ranunculus* was abundant by the side of a stream and elsewhere; and *Colobanthus subulatus* (doubtless the moss-like plant mentioned by Cook) formed large tufts on the south side of the hills. Nine out of the thirteen plants in South Georgia are also found in the eastern part of this southernmost zone of vegetation from Kerguelen to New Zealand, taking these islands together. One, *Juncus novæ-zealandiæ*, had not previously been found in what may be termed the American part of the zone; but, as Prof. Buchanan, to whom Dr. Engler submitted the South Georgian specimens, remarks, this is so nearly allied to the South American *Juncus stipulatus* that it may be cited as another instance of representative and closely allied species in the American and Australian regions.

Thus are we gradually obtaining a knowledge of the vegetation of the detached fragments of the Antarctic flora; yet several islands are still quite unknown botanically or only very imperfectly. Concerning Diego Alvarez, or Gough Island, situated about 4° south of the Tristan d'Acunha group, we know nothing except that the vegetation is said to be similar to that of Tristan d'Acunha, and to include *Phylica nitida*, the only arboreous member of the latter flora. Then there is a group of islands, including Lindsay, Bouvet, and Thomson, in about the same latitude as South Georgia, but 35° eastward, of which nothing is known botanically.

W. BOTTING HEMSLEY.

OWLET MOTHS.

THE beautiful moth which we figure herewith belongs to the family Noctuidæ, or "Owlet Moths." The exceptional size of this moth has attracted the attention of collectors for a long time past. It was figured as long ago as the end of the seventeenth century by Sibylle de Merian, in her plates of the insects of Surinam. This moth, the largest known, was named *Thysania Agrippina* by Cramer, who perhaps, by this name, wished to recall the majestic beauty of the widow of Germanicus.

THYSANIA AGRIPPINA. (Small Specimen; Natural Size.)

This Noctuid, which is not rare in Guiana, expands ten inches in both sexes. The general tint of the upper surface of the wings is of a pale gray. This tone is set off by wide, maroon-brown zigzag lines that form blotches in places. Upon the upper wing, near the base, there is a crescent-shaped spot. Beneath, the four wings are of a dark wine-color, set off by white spots and crescent-shaped markings. The margin of the wings is scalloped. The body is of a yellowish white, and the eyes are black.

The caterpillar of *Thysania Agrippina* is very large, and is remarkable for its glaring colors. As represented by Sibylle de Merian, its head is yellow, and the rings are of a greenish blue, with a broad black blotch covering the back and encroaching upon the sides. A longitudinal yellow stripe runs along the sides. From the next to the last ring rises a little horn, as in the case of the caterpillars of the sphinxes, or hawk-moths. According to the learned Dutch lady just mentioned, this caterpillar lives upon a species of gamboge, and does not seem to feel the effects of this drastic, purgative diet. It is not unusual, however, to see caterpillars accommodate themselves to the most poisonous plants; that of an indigenous sphinx (*Deilephila Euphorbiæ*), for example, lives upon the cypress spurges. Insectivorous birds so well know the toxic properties that this caterpillar thus acquires, that they let it display its brilliant colors with impunity upon the bare stalk of the plant. We do not know whether or not the caterpillar of *Thysania Agrippina* enjoys the same immunity.

This caterpillar undergoes its metamorphoses in a cocoon of coarse loose silk, which is as large as a hen's egg, and is hidden among brushwood.

There is a species belonging to a neighboring genus, *Erebus odora*, which inhabits Jamaica, Guadaloupe, Guiana, Brazil, and the United States. This, too, is a moth of large size, but does not expand over five inches. It is a blackish species, dark as night, and, like most of the Noctuidæ, avoids the light, and delights in sheltered, dark, and moist places. It is not rare to see it enter houses.—*La Nature.*

EXPLORATIONS AND EXCAVATIONS IN ASIA MINOR.

IN a *brochure* just reprinted from the *Archæological Journal*, Mr. R. Popplewell Pullan, F.S.A., F.R.I.B.A., gives a connected narrative of his explorations in Asia Minor, which extended, though not continuously, over a period of twelve years (1857–69), and resulted in the disinterment of some of the finest monuments of Greek architecture, some of which are now preserved in the British Museum.

A map of the west coast of Asia Minor shows the routes followed in the earlier journey, and renders the descriptions more easy to understand. The western coast surpasses, Mr. Pullan remarks, all other parts of the world in the number of its remains of ancient edifices and in the vastness of their dimensions.

It is difficult to go a day's journey without meeting with inscriptions and fragments of architecture which attest the former prosperity of the country and the beauty of its buildings, for it is covered with the ruins of ancient cities, which are full of remains of temples, baths, agoræ, and gymnasia. Mr. Pullan was sent out by the Foreign Office in 1857 to co-operate with Mr. C. T. Newton, especially with the view of obtaining data for the restoration of the Mausoleum, the site of which had, after considerable research, been discovered by Mr. Newton.

Having recovered the sculptures for the British Museum, and made a conjectural restoration, the expedition was in 1858 transported to Cnidus, where they hoped to find some trace of the amphiprostyle temple in which stood the celebrated statue of Venus by Praxiteles. They found that the temple had been rebuilt in late Roman times.

At Cnidus, two vast theaters and an odeum were excavated, and near the city was found a beautiful seated statue of Demeter, one of the best specimens of Greek art. In exploring the district outside Cnidus, Mr. Pullan came upon a sculptured lion lying at the base of a tomb, square in plan, surmounted by a pyramid supported by a tholus. This lion was transported to England, and now stands in the Elgin Room at the British Museum.

Mr. Pullan returned to England in 1859, and in 1861 was commissioned by the Society of Dilettanti to visit the sites of certain temples on the west coast of Asia Minor, when he explored the whole of that coast in boat or on horseback, and succeeded in identifying the sites of Myrina, the Grynæum, and other places. During this tour he visited the sites of Teos, Priene, Apollo Branchidæ, and Cybele at Sardis, and also the cities of Alexandria Troas, Assos, Pergamus, Sardis, Ephesus, Priene, Miletus, Iassos, Euromus, Heracleia, and Magnesia ad Meandrum.

On the Acropolis at Pergamus, he remarked several pieces of sculptured marble which led him to the conclusion, as expressed in "The Principal Ruins of Asia Minor," by Texier and Pullan, that excavations here would yield important results; conjectures subsequently proved to be correct by the unearthing here by the German expedition of the friezes of the splendid Altar of Giants.

At Ephesus the author noted in the piers of an aqueduct which conveyed water to the castle—an edifice about two miles from the ancient city — several mouldings which from their size and style evidently must have belonged to the celebrated Temple of Diana, and the Temple was actually discovered by Mr. J. T. Wood on this side of the city, not very far from this aqueduct, after eleven years of exploration.

Mr. Pullan candidly confesses that at that time he shared the common opinion that the Temple stood at the head of the port on the other side of the city. On his way back to England, Mr. and Mrs. Pullan were the guests at Smyrna of Mr. Wood, then architect to the Smyrna and Aidin Railway.

"When I left for England," Mr. Pullan adds, "Mr. Wood expressed a desire to discover the site of the Temple of Diana of Ephesus. I accordingly introduced him to Mr. Newton, who obtained for him the support of the trustees of the British Museum, and to Mr. Wood's remarkable preseverance under great difficulties and discouragements we owe the recovery of the architectural remains of that temple which are in the British Museum."

In 1866 Mr. Pullan again proceeded to the East to excavate the temple of Apollo Smintheus for the Dilettanti Society. Here there was no heap of ruins, nor any indication of the site, except the drums of columns seen by Admiral Spratt. After some weeks' search he ascertained that the site was covered by gardens, and that the foundations only were *in situ*.

The temple proved to be of remarkable character, differing from all known examples. It was of the Ionic order, pseudodipteral and octastyle, with fourteen columns on the flanks, and surrounded by a grand flight of ten steps. The capitals were more than usually ornamented; the temple stood in a valley remote from any city, Alexandria Troas being the nearest city of importance.

The Troad is full of unidentified sites; one of these, viz., Scepsis, the author was enabled to identify during a short tour into the interior. He returned in 1867, and two years later was commissioned by the Dilettanti Society to undertake the charge of the expedition for excavating the Temple of Athenê Polias at Priene, a building designed by the architect of the Mausoleum.

After six months' work—interrupted by fever, which attacked the whole party—the heap which covered the temple was removed, and beneath it was found the pavement entire, the walls of the temple standing 5 ft.

or 6 ft. all round, two of the columns remaining in to a height of 15 ft., several fragments of the colossal statue of the goddess, and several other fragments of sculpture; among these there was an archaic head of a female and a bust of Roman times.

The temple was hexastyle, of the Ionic order, of fine character. Mr. Newton paid the explorers a visit when the excavations were approaching completion, and made arrangements for the removal of the sculptures and inscriptions to England.

These were presented to the British Museum by the Dilettanti Society, and are now arranged in the Mausoleum room, so that the architectural features of the Temple of Athenè may be compared with those of the Mausoleum with the aid of Mr. Pullan's drawings of these edifices, hung upon the walls in the same room.

THE FORM OF THE EARTH.

ON the first of March, the Geological Society begun a series of lectures which it proposes to have delivered by some of its members at its periodical gatherings, for the purpose of summing up a certain number of questions pertaining to geology. Mr. De Lapparent, the learned author of the *Traité de Geologie*, had the honor of inaugurating these lectures, and the subject selected by him was the form of the earth. We give a brief summary of the interesting facts stated by him.

It has been a popular idea for a long time, that the mean level of the seas remains identical, without change or variation. The seas, influenced by both gravity and centrifugal force, have been considered as having taken a position of equilibrium in such a way as to give the earth the form of an ellipsoid of revolution. Besides, as no modification supervened in the action or the intensity of these two forces, the figure of the earth and that of the ocean is invariable. If, then, despite this necessary stability of the seas' level, changes occurred in the shore lines (and many have occurred), they can be attributed only to the mobility of the solid crust of terra firma. It is thus that the upheaval of certain portions of our globe and the subsidence of others have been spoken of, and it has been peremptorily shown that in one place terra firma gains ground and that elsewhere it loses it. New Zealand, Spitzenberg, Scotland, and Chili are good examples of regions that have emerged, while Scania and Brittany represent countries that are in the act of subsiding. Now, according to the theory that attributes absolute constancy and stability to the mean level of the seas, nothing but movements of the ground, of terra firma, can be invoked to explain these upheavals and subsidences.

Without any desire to discuss at length the possibilities of these movements of the ground, Mr. De Lapparent asked whether we might not invoke other causes, and whether we might not explain the phenomena just mentioned by modifications that have occurred in the equilibrium of the mass of the seas. We know that a pendulum, when freely suspended, always takes a vertical direction, being attracted by the mass of the earth; but we know likewise that the vicinity of a mountain prevents the pendulum from taking a position of equilibrum, or, rather, modifies the latter very sensibly. It attracts the pendulum as does the rest of the terrestrial mass, but its action is necessarily quite feeble—not enough to be appreciable—and it has been found that the pendulum takes a different position of equilibrium from that which it would have in the absence of a mountain chain. This position is the resultant of two different attractions of unequal intensity. Owing to this fact, which is indisputable, we may, and ought to, ask if terra firma must not exert upon the ocean masses an action identical with that which they exert upon the pendulum; whether they do not attract the sea to them; and whether the latter's level is not superelevated, with respect to the mean, ideal level, in the vicinity of continents and islands.

Saigey, in 1842, and then Fischer, Listing, and Bruns, studied this question, and reached the conclusion that, effectively, the vicinity of solid masses of the crust exerts a very decided influence upon masses of liquid. Listing, taking into consideration the great distortions which must result from such influence, has created the term *geoide* to designate the terrestrial ellipsoid distorted by local attractions. By calculating, he has reached the conclusion that these attractions have an intensity such as to be able to vary the surface of the sea a thousand yards, with respect to the level of the mean ellipsoid. Continents attract masses of liquid to such a point that, if we suppose, for example, the section of the ocean between Havre and New York to be spread out on a plane surface, a vessel leaving the latter city would at first find herself upon a liquid hill, which she would descend in measure as she left the continent, and reach, toward the middle of her trip, the bottom of a valley whose opposite declivity she would mount, and reach the summit of another liquid hill, whose culminating point would be Havre. One fact that contributes to demonstrate that the level of the sea at a distance from a continent, and in the center of the oceanic mass, is less than the mean level, is the excess of the pendulum's attraction. Mr. Faye, it is true, in an article published some time ago in the *Revue Scientifique*, wishes to show that this excess of attraction may be due to the fact that the sea considerably cools the solid, subjacent crust, whence a considerable thickening of the latter and an excess of attraction.

To this, Mr. De Lapparent responds that, through the several miles thickness that must be allowed the earth's crust, the cooling action of the sea (supposing the latter at a temperature of 1 or 2 degrees) could not be diffused. Apropos of this, he cites a topical example. At Jakoutsk, the annual mean of the earth's temperature, at the surface, is not 1 or 2, but −10 degrees. At 400 feet beneath the surface the temperature is 0° at the most, and we have found spurting water, which is a proof that the cooling is propagated to but a slight distance in the crust, and that it is quickly counterbalanced by the internal heat of the globe. How, then, after this example, can we believe in the propagation of the refrigeration of 0° or 1°, say even −1° or −2°, through a thickness of several miles? In fine, if there is an excess of attraction of the pendulum over the level the sea, it is not because the terrestrial crust is thicker, but because of the depression due to the attraction of the latter by continental masses.

From what precedes, it must be calculated that all the measurements made up to the present, and based upon the regularity of the earth's figure, are erroneous. The earth possesses a very irregular figure, and, in order to get at its mean volume, everything must be done over again.

The figure of the ocean's surface is not only irregular, but variable. There are undoubted traces of these variations, and we have seen that a certain theory would explain them by the mobility of the solid crust solely. Let it be so; let us accept the hypothesis of the mobility of the emerged ground; but is that the only thing possible? Assuredly not, for there is reason, in the very first place, for taking different agents into account, such as the action of currents and winds, and the inequality of tides, according to the depth of the fjords where they make themselves felt. But such agents can be called on solely to explain slight shiftings of shore lines. One other agent, and a very interesting one, is pointed out by Mr. De Lapparent. Suppose, says he, that, in a mountainous country, surrounded by seas, there form masses of ice and immense glaciers as a consequence of meteorological conditions, as in the polar regions, where there are some that are 60 miles wide and several thousands yards high. Will not the masses of ice have the effect, just as a continent or mountain would, of attracting the liquid masses around them, and would not the level of the sea around the same country be successively elevated and depressed if the quantity of ice were to increase and then diminish? Ought not the different levels of the shore line to

A B C—Surface of the sea in the hypothesis of a non-distorted spheroid. D E F—Real surface of the sea.

correspond to different quantities of ice in the mass of liquid? The deduction appears to be perfectly logical, and it is to be remarked that, according to Penck, the countries in which there has occurred the most marked shifting of the shore line in quaternary and recent epochs are precisely those in which glacial phenomena have exhibited themselves with most force. It seems, then, that we ought to establish a direct relation between the oscillations of the sea level and the variations that the ancient glaciers have presented, the level being low when the glaciers did not exist, and high when they began to develop, and being very high when they attained their maximum of power, to become very low when they disappeared. The thing appears to be very probable, and calculation indicates that it is possible, the attraction exerted by the ice being more than sufficient to explain some very important variations in the ocean's level.

Let us add that, in the Gulf of Naples, the existence of oscillations of the sea level has been noted, and these were connected with oscillations of lava in the craters of Vesuvius. These would be explained by the same mechanism, the level rising or falling according as there was or was not an abundance of lava. In fine, the hypothesis emitted by Mr. De Lapparent is very plausible, and the solution that he proposes for certain cases is very happy. Even though there were no reason to adopt his theory exclusively, the fact would have to be recognized that it has two advantages. It does not conflict with any known phenomenon, and is, on the contrary, connected with positive theories of great generality. On another hand, it is capable of explaining certain facts that are not explained by other theories.

This is more than is necessary to attract the attention of those who are interested in the natural sciences and the problem of our globe.—*La Nature.*

AUSTRALIAN CAVES.

THE *Darling Downs Gazette* describes some recently discovered caves fifteen miles from Rockhampton, Queensland. A party, headed by Mr. W. M'Ilwraith, of the Rockhampton Natural History Society, recently visited the caves. From some wells on the route they saw the peaks of an uncommon range of hills. "They stand up in a fine sharp profile like the pinnacles and turrets of a stately Gothic pile. The vestibule of the wonderful structure is formed by an immense chasm in the rocks. Two walls of limestone or marble rock set in an acute angle rise on either side to a height of about 60 feet, and converge in front at a higher elevation. At nine o'clock at night the party began exploring, and after clambering over a mass of detached, sharp-edged, pock-pitted rocks, got into a rocky chamber. Its walls were beautifully white in parts, and show the rock to be of limestone formation. They visited in succession caves of different dimensions, and named one the 'Chinese Joss-house.' It is a little recess off the passage: the walls are beautifully white, and stalactites and stalagmites unite to form beautiful pillars, the whole being wonderfully beautiful, reminding the visitors of Chinese ivory carved work. In the morning they continued their exploration, wandering through numerous passages, and crawling and slipping till they came to a large cavern. In one of the passages the bats extinguished their candles, and they returned to the upper regions. They then saw daylight streaming from the opposite side of the mountain, and estimated the distance from light to light at five chains or more. They returned to the starting-point, climbed a ladder, and traversed other passages, and crossed a gulf on a bridge formed of saplings. Eventually they reached a wide opening, and the light poured in from an opening in the caves. This latter is a large chamber, and in it are the roots of a tree, which have taken hold in the bottom of the cave, and hang like ropes. The most striking stalagmites in it resemble the head of an elephant and the bust of a man. Various caves were discovered, and also openings leading from one main suite of caves to another one. The cave particularly alluded to is called 'The Cathedral.' It is 50 feet long from the porch to the pulpit stairs, 30 feet across, and the ceiling is so lofty that the gleams of the candle did not reach it. There are stalactitic formations on the ceilings and floor, but the walls are plain, and have niches in some parts. Some of the party descended 60 feet here, and in another failed to reach the opening. The writer says: 'Wherever we went almost underground our footsteps had a hollow sound, and the conclusion we come to at present is that the region has been a hot-spring area, and the caves were formed by the action of hot water.'"

STRESS AND STRAIN.

THE torsional elasticity of all metals is temporarily decreased by rise of temperature between the limits of 0° C. and 100° C., the amount of decrease per degree rise of temperature increasing with the temperature. To this may be added that the percentage decrease of torsional elasticity produced by a given rise of temperature is for most metals about twenty times the corresponding percentage increase of length.

If we start with a sufficiently low temperature, the internal friction of all annealed metals is first temporarily decreased by rise of temperature and afterward increased. The temperature of minimum internal friction is for most annealed metals between 0° C. and 100° C.; for most hard drawn wire, however, the temperature of minimum internal friction is below 0° C.

The temporary change, whether of the nature of increase or decrease, wrought by alteration of temperature in the internal friction of metals, is in most cases enormously greater than the corresponding change in the torsional elasticity.—*Herbert Tomlinson.*

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